21st Century Innovations in Air Transportation

John D. Odegard Memorial Lecture

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NASA Langley Research Center
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University of North Dakota

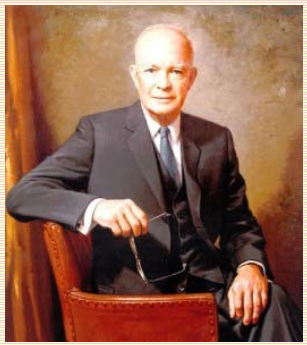
Outline

- **Historical and Technical Context for 21st Century Alternatives in Air Transportation**
  - ***Our nation's history of transportation system innovation is based on disruptive technologies.***
  - ***We are at a crossroads in air transportation.***
- **Enabling Technologies Affecting Alternatives in Air Transportation**
- **Leading Indicators in Aviation Innovation**
  - ***New aircraft***
  - ***New avionics***
  - ***New operating capabilities in the National Airspace System***
- **New Options for Use of Smaller Airports and Smaller Aircraft for Public Transportation**

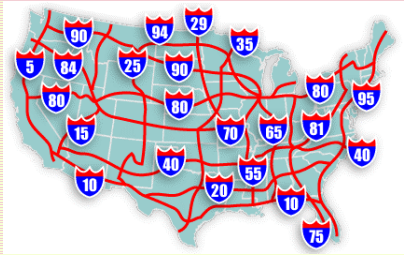
Two Centuries of Historical Context for Disruptive Innovation in Transportation Systems

Jefferson sends Lewis and Clark to search for a path for commerce

The Transcontinental Railroad connects east and west

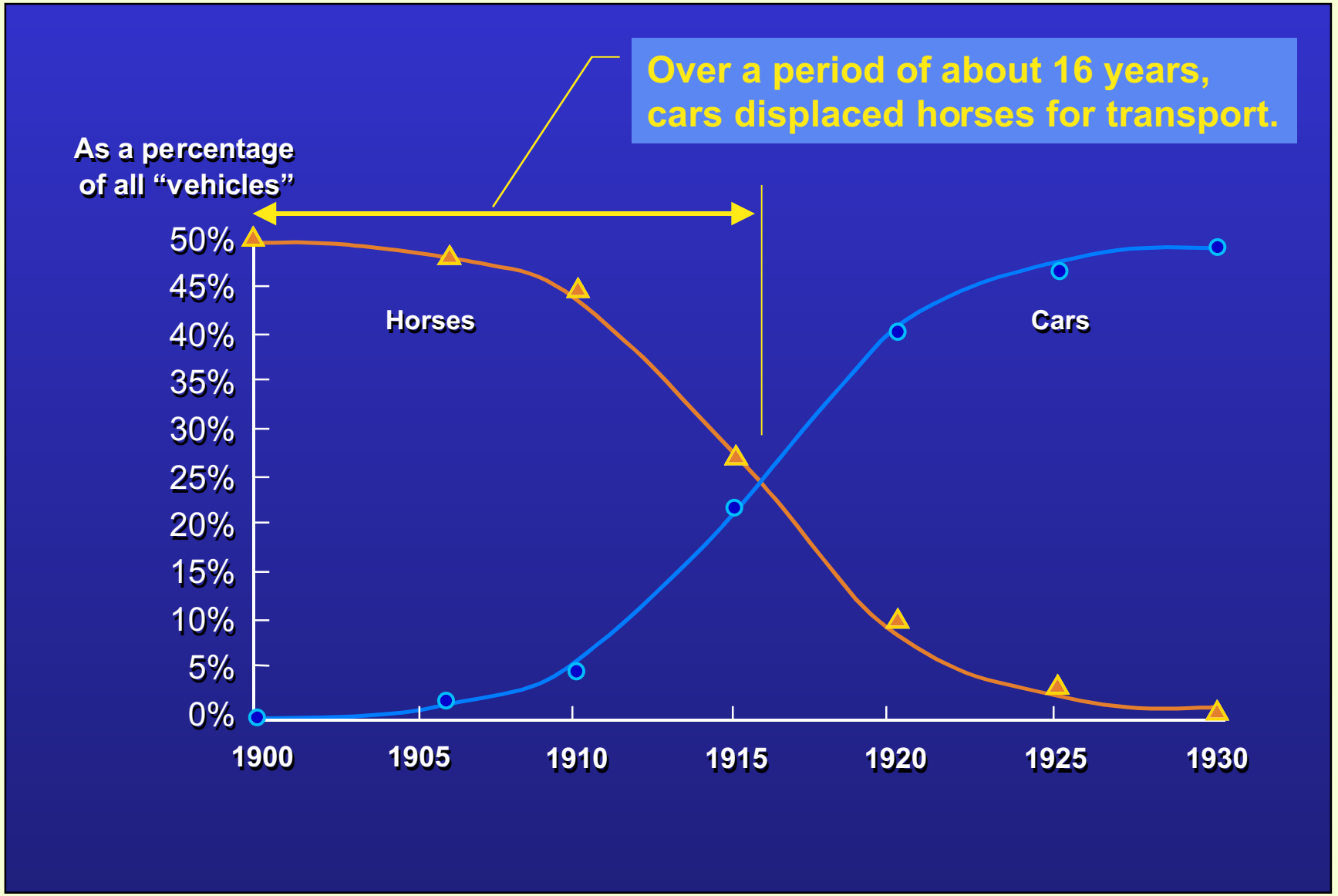


The Interstate Highway system connects the nation's cities

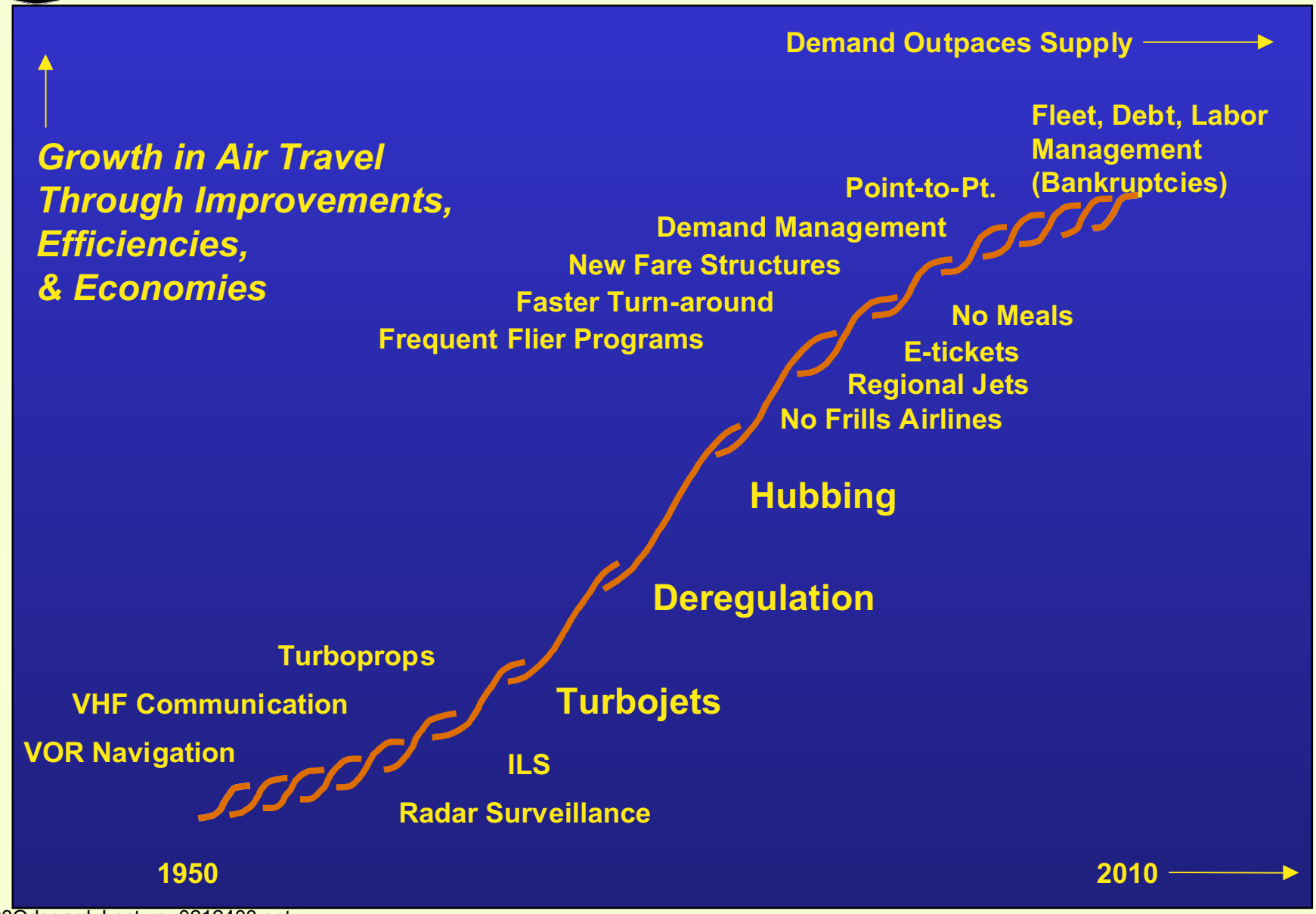


The Substitution of Cars for Horses

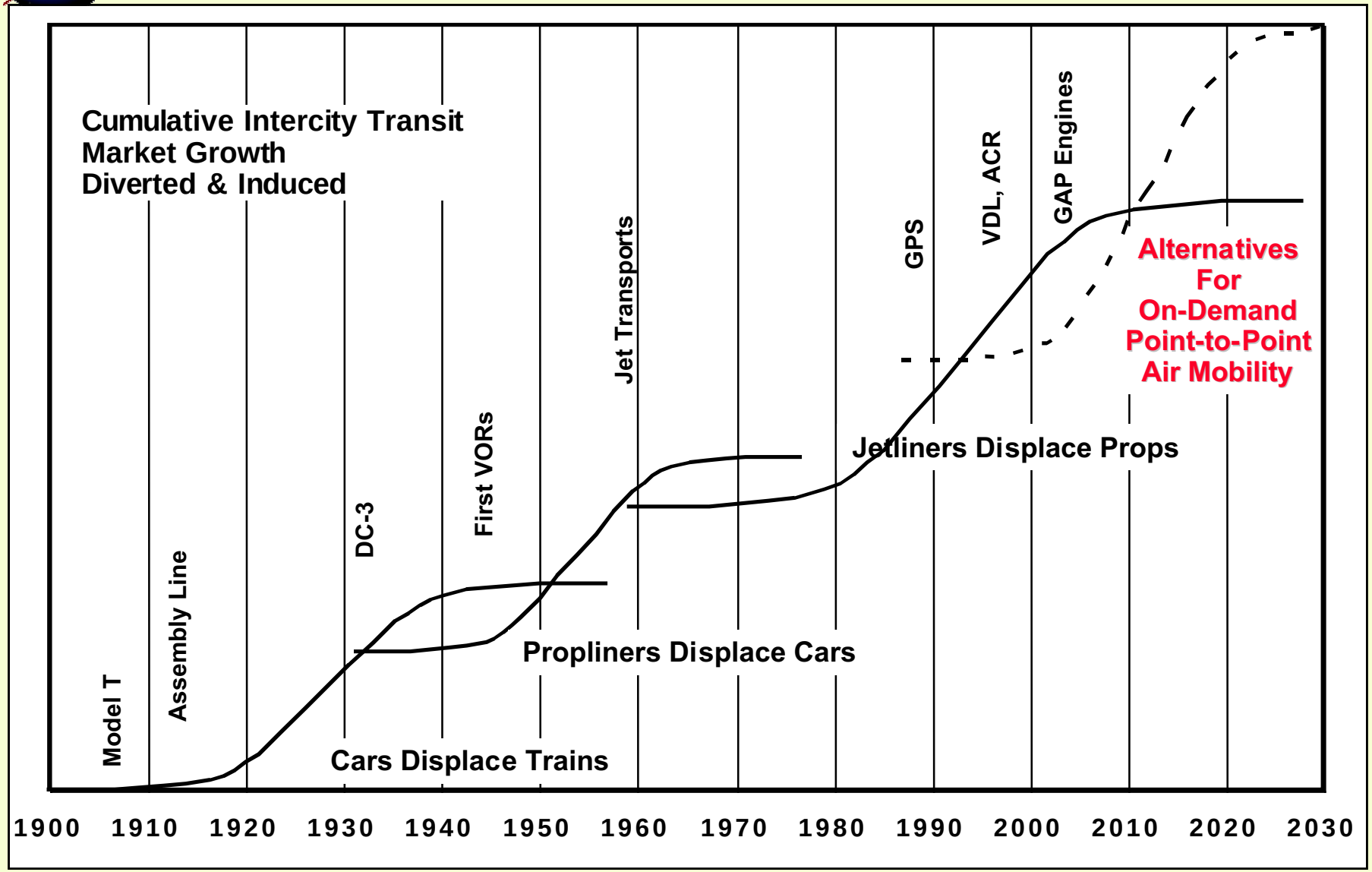
N. Nakicenovic (1986)



A Notional Life Cycle of The Hub-and-Spoke Innovation

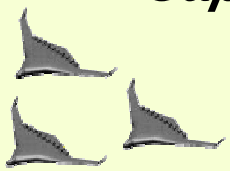


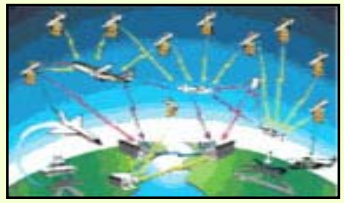
Notional Life Cycles in Higher-Speed, Longer-Range Daily Travel

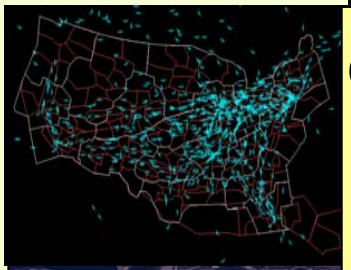


Integrated Advancements In Airspace and Aircraft

Airspace Capability







- Ubiquitous Airspace Accessibility
- Automated Airspace Procedures
- Distributed Air-Ground Procedures
- NAS Evolution

Current State
Hub & Spoke
Long-Haul
GA

Future State
Multi-State:
On-Demand, Point-to-point
& Hub Systems

Cost
Environment
Safety/Security

Point-to-Point

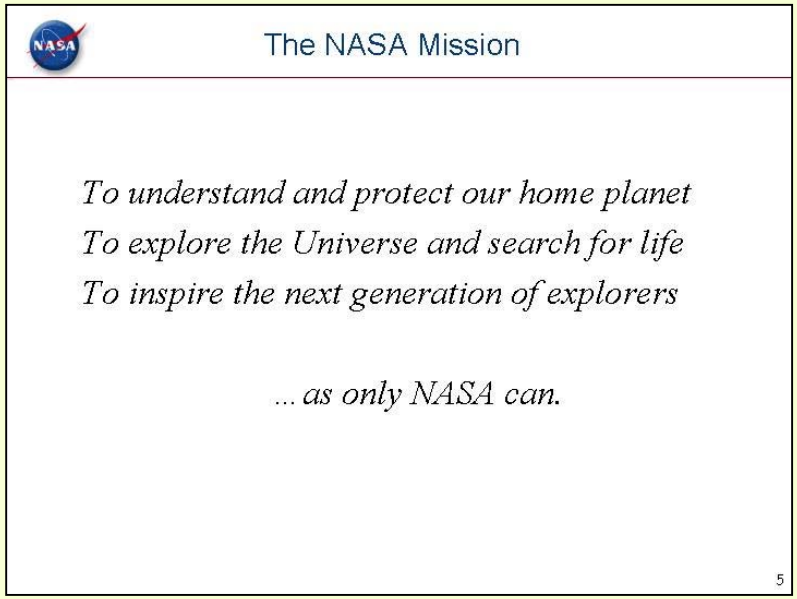
UAV's

Green Aircraft

Aircraft Utility

Technical Context for Mobility Alternatives

- Moore's Law on microprocessor performance
- Gilder's Law on bandwidth performance
- Metcalf's Law on network performance
- The unwritten law of abundance
- The unwritten rule of gridlock
- Kurzweil's Law of Accelerating Returns
- The Golden Rule of the information age

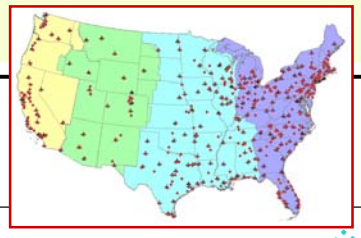


The Difficulty About Predictions…

- **"The telephone has too many shortcomings to be seriously considered as a means of communication."**
  – Western Union executive, 1876
- **"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)
- **"I think there is a world market for maybe five computers."**
  – IBM Chairman Thomas Watson, 1943
- **"Computers in the future may weigh no more than 1.5 tons."**
  – Popular Mechanics, 1949
- **"There is no reason for individuals to have a computer in their home."**
  - DEC Chairman Ken Olson (DEC), 1977
- **"640,000 bytes of memory ought to be enough for anybody."**
  – Microsoft Chief Software Architect Bill Gates, 1981

If Time is Gold

Then Door-to-Door Speed is the Coin of the Realm



Better

Door to Door Trip Speed, MPH

A 500 mile trip average speeds:

- **200 mph by jet taxi**
- **100 mph by propeller airplane**
- **75 mph by airlines**

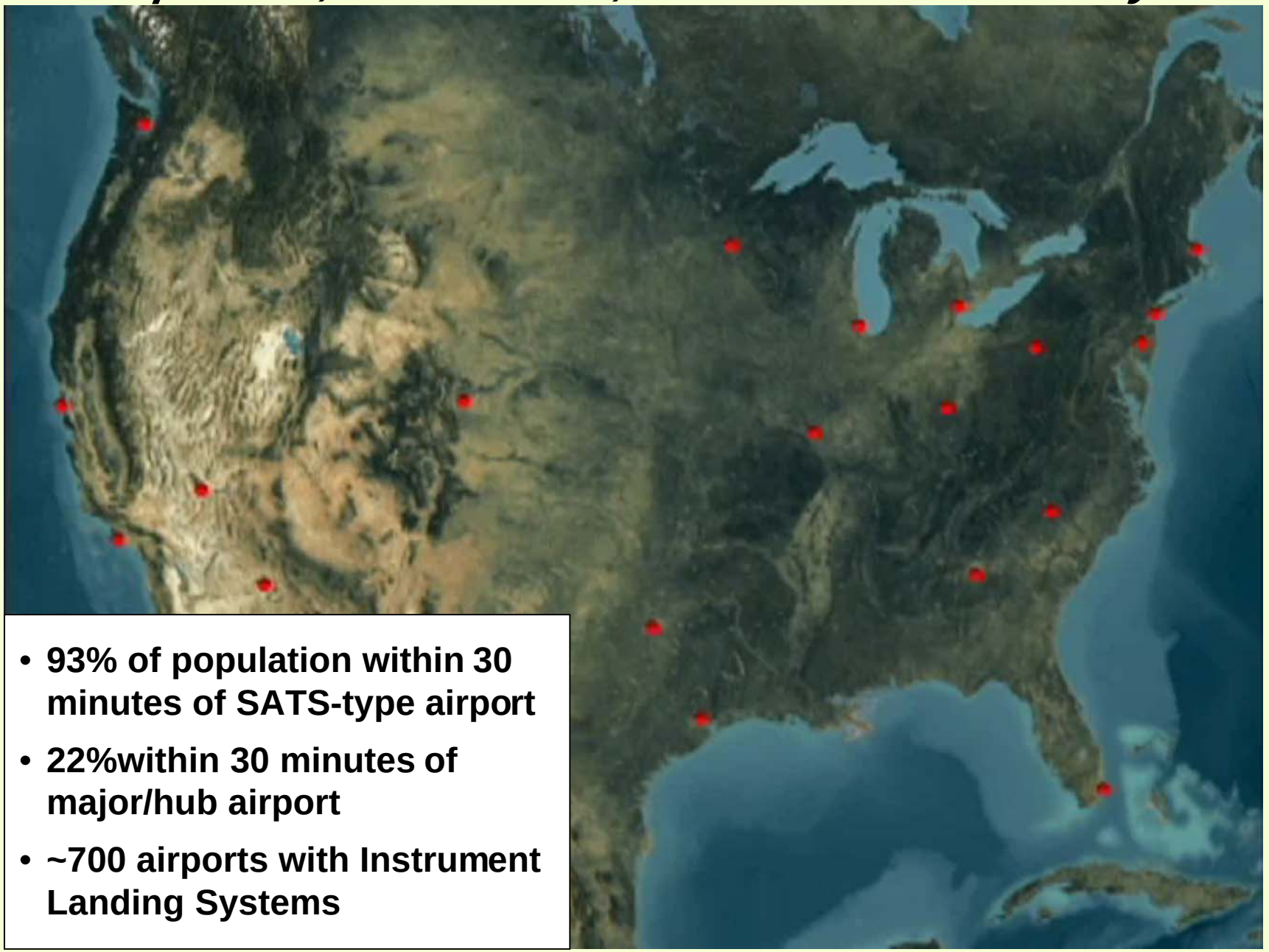
Scheduled Service
Jet Air Taxi
Prop Air Taxi
Car

0
50
100
150
200
250
300
350

0
500
1,000
1,500
2,000
2,500
3,000

One Way Trip Distance, Miles

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**

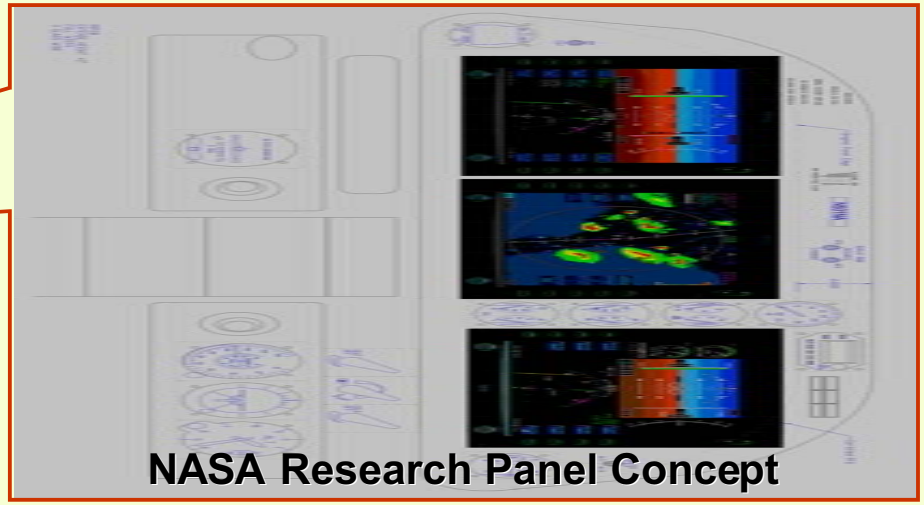
Innovations Affecting Early 21st Century Aviation

- All-Digital Cockpit Systems
- Synthetic/enhanced vision systems
- Intuitive graphical flight path guidance
- Digital Radios/Datalink (Radio Modems)
- Airborne Internet
- Airborne weather information graphics
- Electronic PiReps
- Airport/Airspace Management Software
- Non-towered airports procedures
- Self-separation
- Collaborative sequencing
- Non-traditional navaids and surveillance
- Airport Databus
- And others …

Public-Private Consortium Membership

SATS Research Aircraft

NASA 501 Cirrus SR-22X


NASA Research Panel Concept

- **Digital, all-electric cockpit system architecture**
  - **Dual avionics computer resources, databus, reversionary displays, and redundant power sources**
  - **Fully integrated IFR primary flight display (PFD)and multi-function display (MFD)**
  - **Digital radios / datalink for ADS-B, FIS-B, CPDLC, D-ATIS, AMM-Comm**
  - **GPS / DGPS / RNP RNAV**
  - **Synthetic vision-based terrain & obstacle graphics**
  - **Intuitive flight path guidance**
- **Research Software Development**
  - **Self-Separation: Conflict Alerting and Conflict Prevention Graphics (ASI, VSI, Nav-Hdg)**
  - **Sequencing software and graphics (Requested Time of Arrival - RTA waypoints)**
  - **Self-Controlled Airspace "Rules of the Road"**

Airborne Internet Preliminary Demonstration

Accomplishment

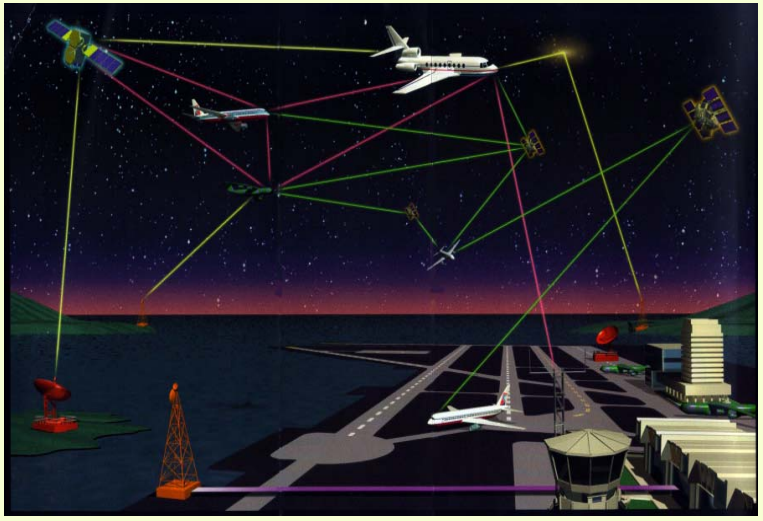
Demonstrated integrated communications, navigation, and surveillance architecture in lab testbed

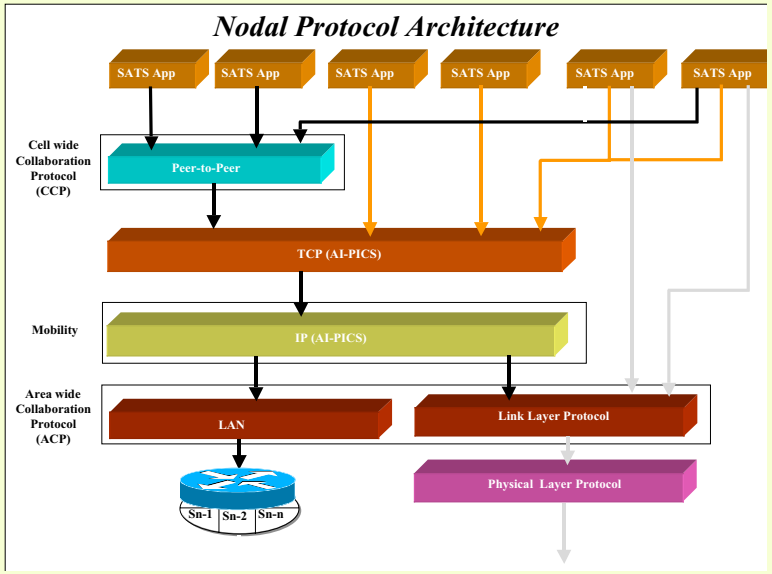
Benefits

- Mobile and policy-based routing
- Service priority communications
- Secure network communications
- Point-to-point, point-to-multipoint, and broadcast addressing
- Based on open standards and protocols.
- Minimizes number of radios and antennas on an aircraft—goal is single radio for all data communications

Plans

- Evaluate candidate communication architectures
- Plan flight evaluations in 2005
- Airborne Internet Consortium Development



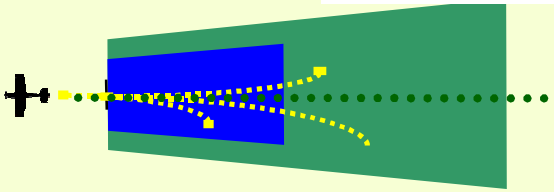


Small Aircraft Transportation System Project

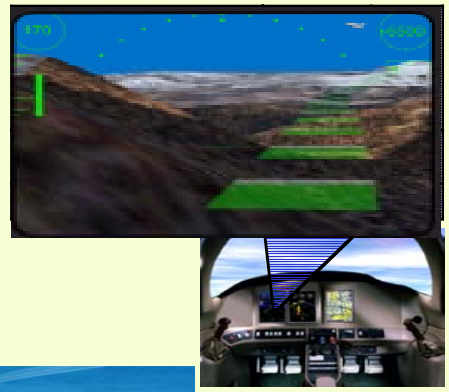
Operating Capabilities for Access to All Communities/

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

Lower Landing Minimums at Minimally Equipped Landing Facilities

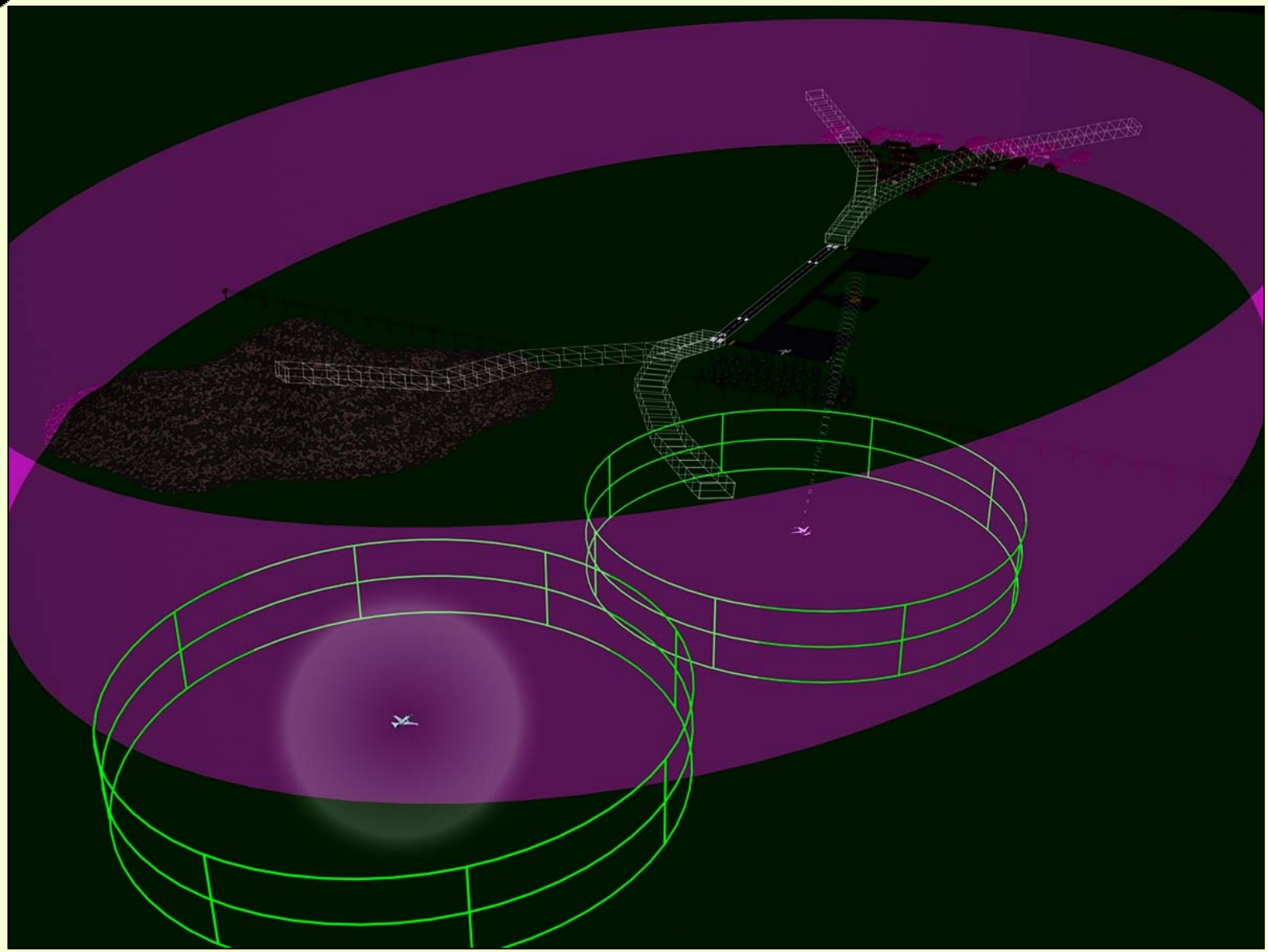


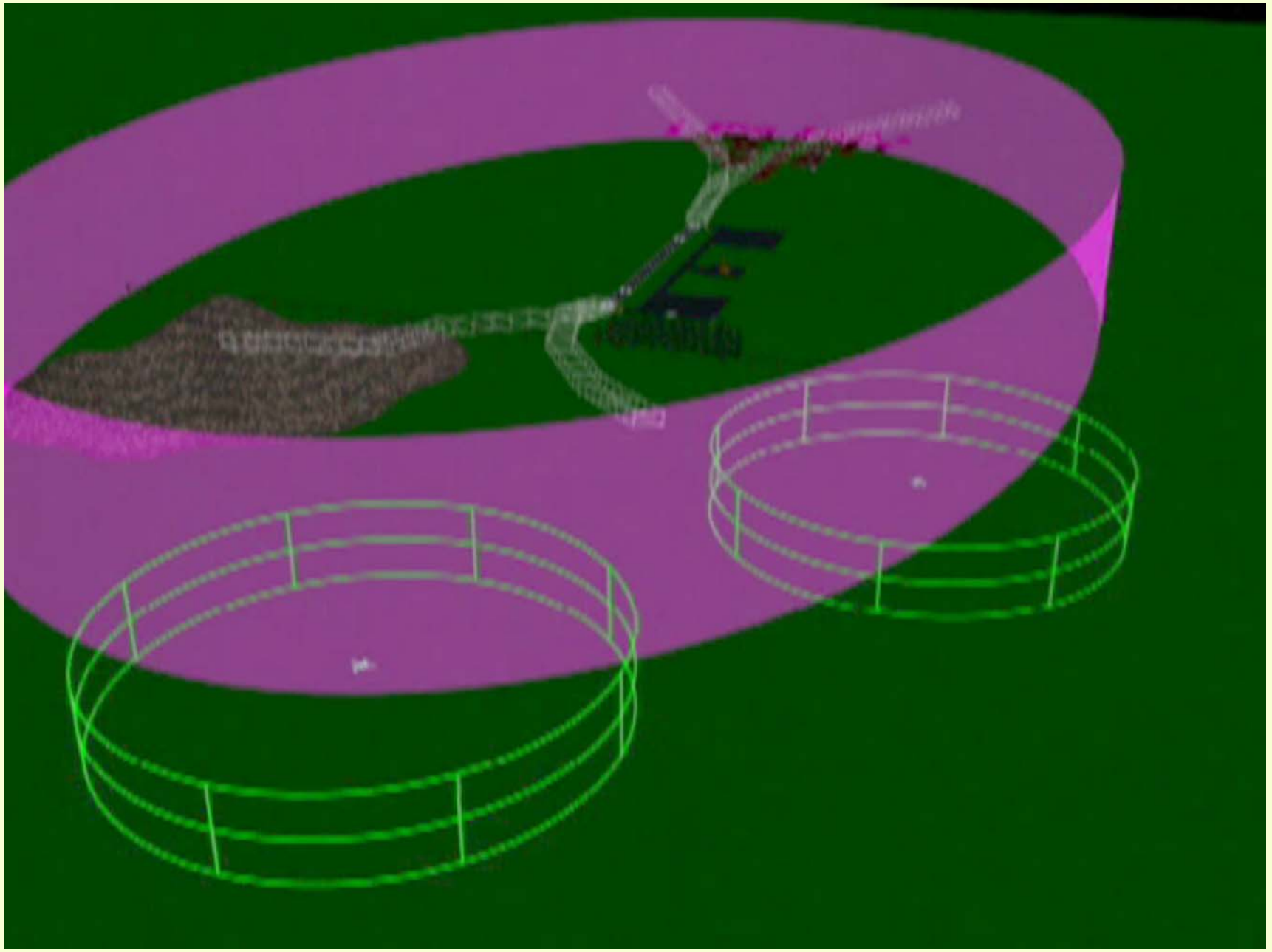
Increase Single-Pilot Crew Safety & Mission Reliability



En Route Procedures & Systems for Integrated Fleet Operations

SATS Operating Capabilities





Leading Indicators in Aviation Innovation

- **Studies reveal new aircraft, technologies, and business plans approach the cost and service thresholds for on-demand, decentralized air travel alternatives to hub-and-spoke travel.**
- **While we cannot know exactly what forms of travel services consumers will see, NASA's aviation technology strategies assume a "multi-state" for 21st Century air travel:**
  - **On-demand decentralized, plus…**
  - **Hub-and-Spoke, plus…**
  - **Point-to-Point Services**
- **The potential effects on aviation are pervasive:**
  - **New operational capabilities at more runway ends**
  - **Alternatives to traditional terrestrial communication, navigation, and surveillance systems**
  - **Increased demand for information-technology services**
  - **Potential for increased operations at smaller airports in the longer-term**

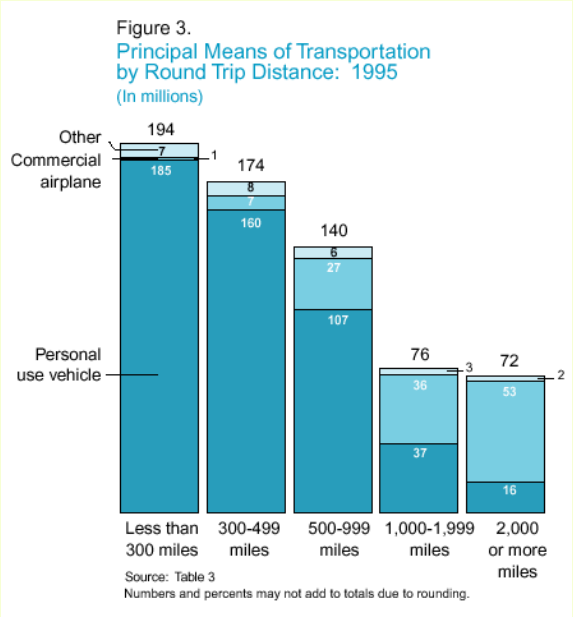
A Revolution in the Cost of Speed

Toyota

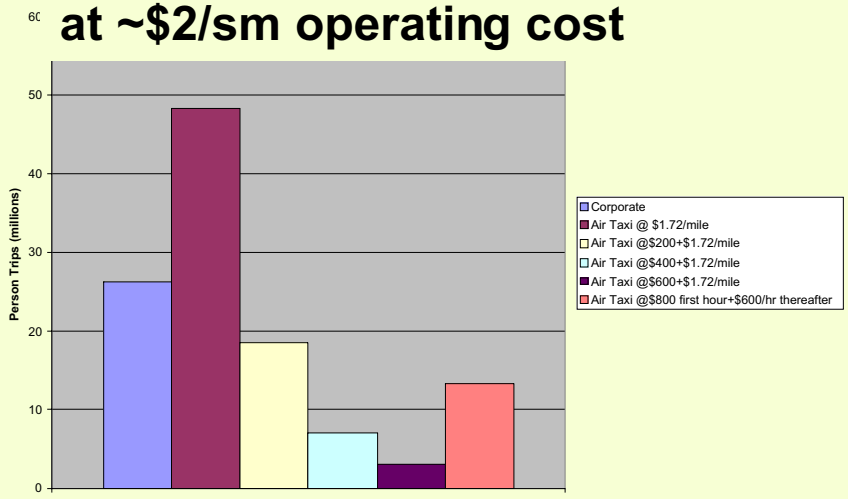
Honda

Future Aircraft Market
Demand and Sensitivity Assessments

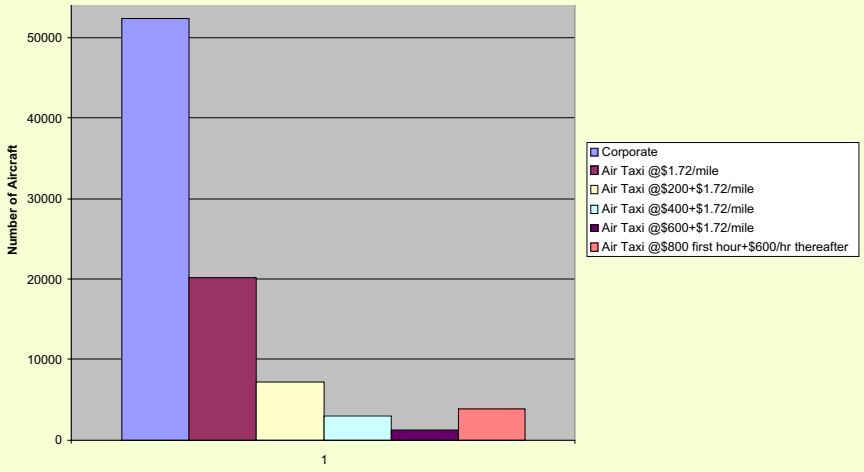
- **Data Source - 1995 American Travel Survey + 2000 US Census**
- **Tools - Modified Integrated Air Transportation System Evaluation Tool (IATSET)**
- **Approach - The IATSET is a macro economic model and predicts at a National level the mode choice between automobile, scheduled air, and on-demand air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



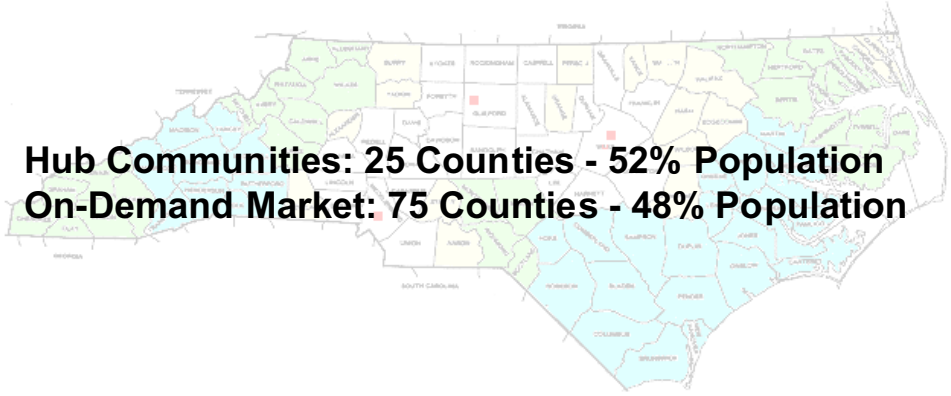
Between 13 and 47 million trips at ~$2/sm operating cost



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



North Carolina Market Assessment for On-Demand Business Travel



Assumptions

- Business Travel
- 98% Accommodation @ ≤ 3 hours
- 175 fleet of Eclipse/Safire/Adam-class Jets
- $1.85 per passenger ticket mile
- No weather impacts

Findings

- Case Study Analyses + Business Case Analyses + Assumptions = 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"

What Challenges Lie Ahead?

Vehicle Systems: A further revolution in the cost of vehicle speed is needed for:

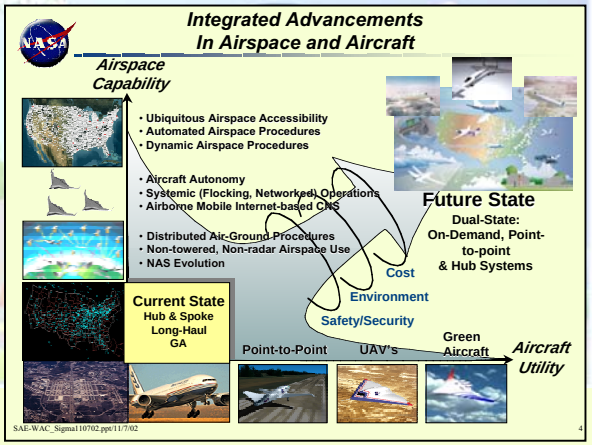
- Shorter range, intra-urban, multi-point distributed mission (<100 miles)
- Mid-range, inter-city point-to-point missions (100-1,000 miles)
- Longer range (>2000 mile) high-speed missions (supersonic overland)

Airspace Systems: A further revolution in airborne and airspace technologies and procedures automation for reliable ubiquitous accessibility:

- Intuitive display systems
- Intuitive control systems
- Intuitive NAS procedures

Summary

- Studies reveal the cost and service thresholds for on-demand, widely distributed air travel alternatives to hub-and-spoke and highway travel may be reached with new generation aircraft and airspace technologies.
- While we cannot know exactly what forms of travel services consumers will see, NASA's aviation technology strategies assume a "multi-state" for 21st Century air travel: On-demand + point-point + hubbing services
- The potential effects on 21st century aviation are pervasive:
  - Aircraft capabilities
  - Airspace architectures
  - Airport infrastructure
  - Pilot requirements
  - Public mobility
  - Economic opportunity




From Wheels on America
to Wings on America
Equitable
On-Demand
Widely Distributed
Point-to-Any Point
21st Century Air Mobility