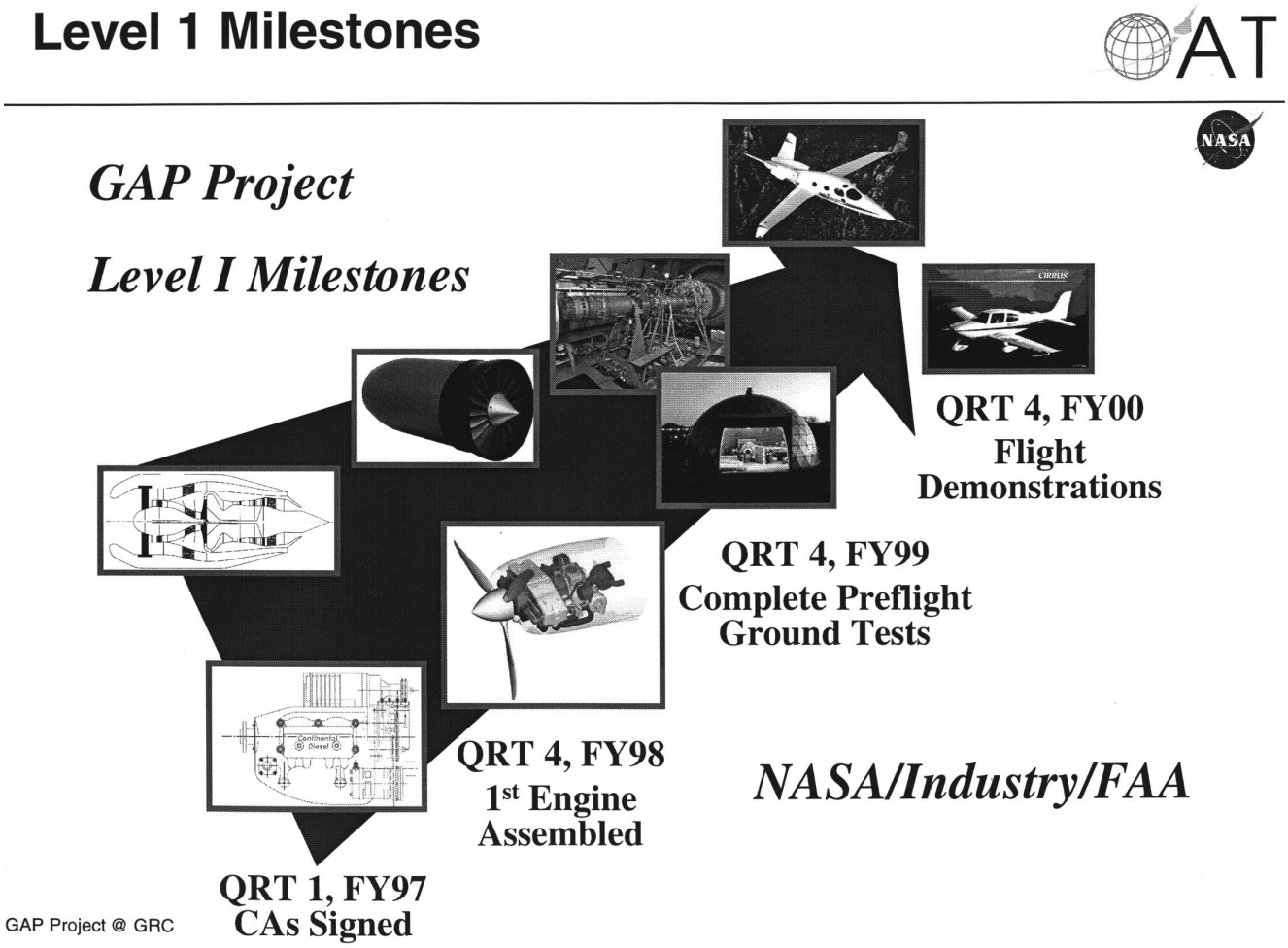
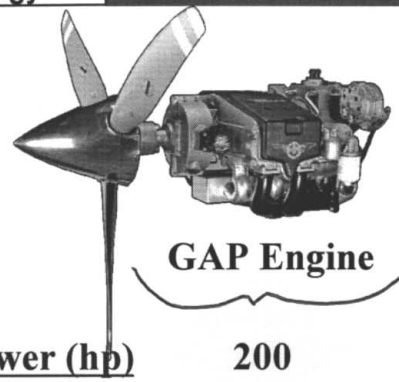
Leo A. Burkardt
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio



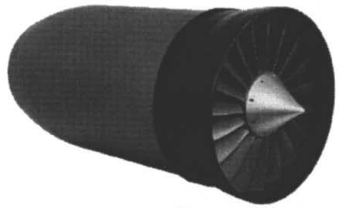
Trend Setting Revolutionary Engines

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities



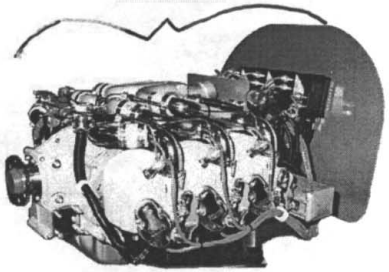
GAP Engine



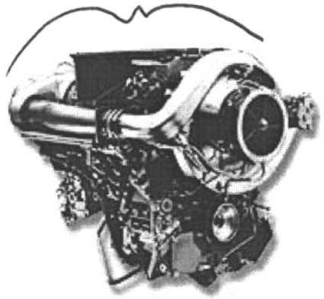
FJX-2

IO 360 ES		GAP Engine
210	Power (hp)	200
420	Weight (lb)*	~ 420
Gasoline	Fuel	Jet
Air	Cooling	Liquid
0.45	bsfc	0.36
$30K	Cost	~ $15K**
1800	TBO (hr)	3000
Noisy & Harsh	Comfort	Quiet & Smooth

Allison 250-B17C Turboprop		FJX-2
	Thrust (lb)	700
420	Power (hp)	~ 500
195	Weight (lb)	< 100
0.66	bsfc	< 0.5
$230K	Cost	~ $65K**
3500	TBO (hr)	5000
1750	Hot Sec. (hr)	2500



IO 360 ES



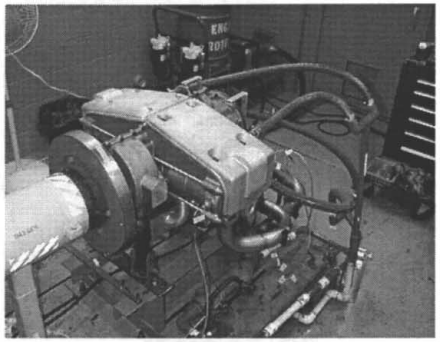
Allison 250-B17C Turboprop

* Installed Weight (Including Fluids)

** Production Rate ~2000/year

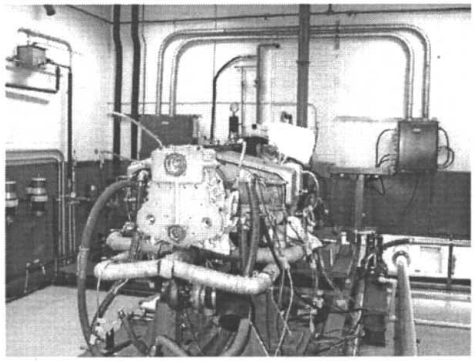
26

Diesel Making Good Progress

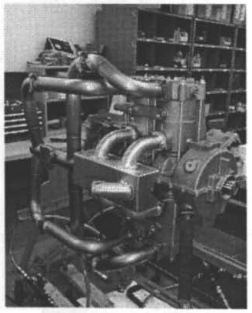


Engine In Test Cell

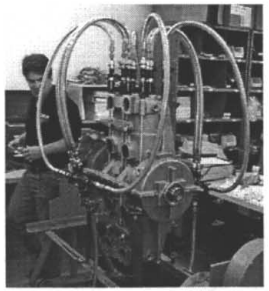
- Component fit and assembly thoroughly assessed and tested
- Development engine testing in progress



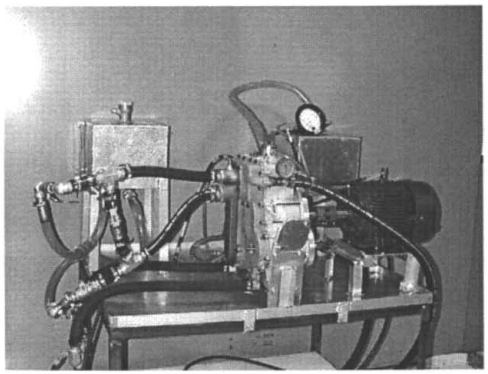
Engine In Test Cell



INTAKE & EXHAUST



THRU-BOLT TENSIONING

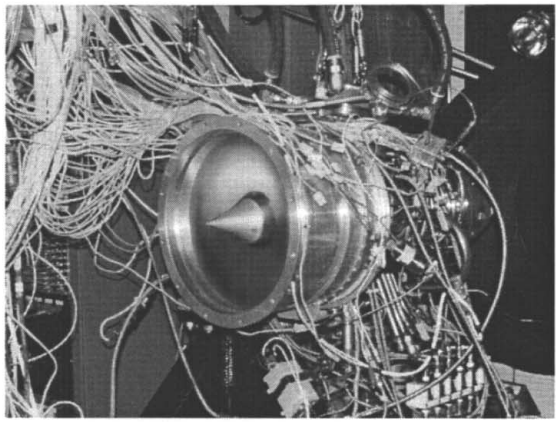


ACCESSORY DRIVE TESTING

GAP Project @ GRC

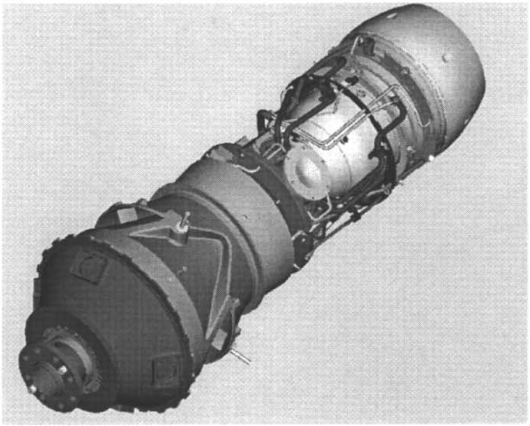
PROPERTY OF TELEDYNE CONTINENTAL MOTORS - PATENTS PENDING 1/29/99

FJX/TSX Making Good Progress

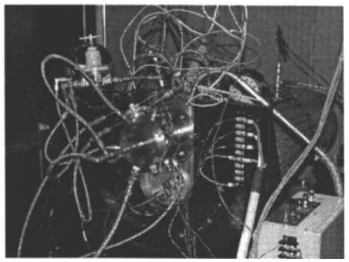


Full Engine In Test Cell

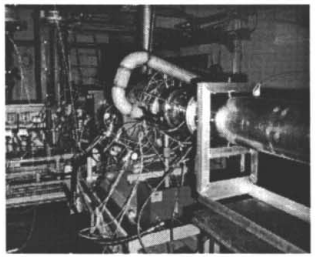
- Key components thoroughly tested in rigs and core engine
- Development engine testing in progress
- TSX-1 gearbox assembly in progress



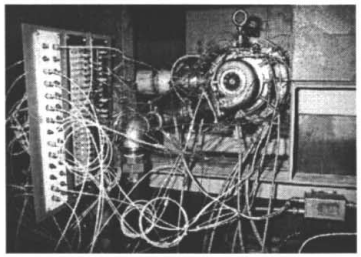
TSX-1



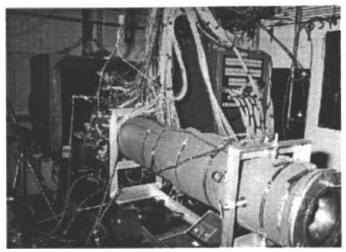
Starter/Alternator



Compressor

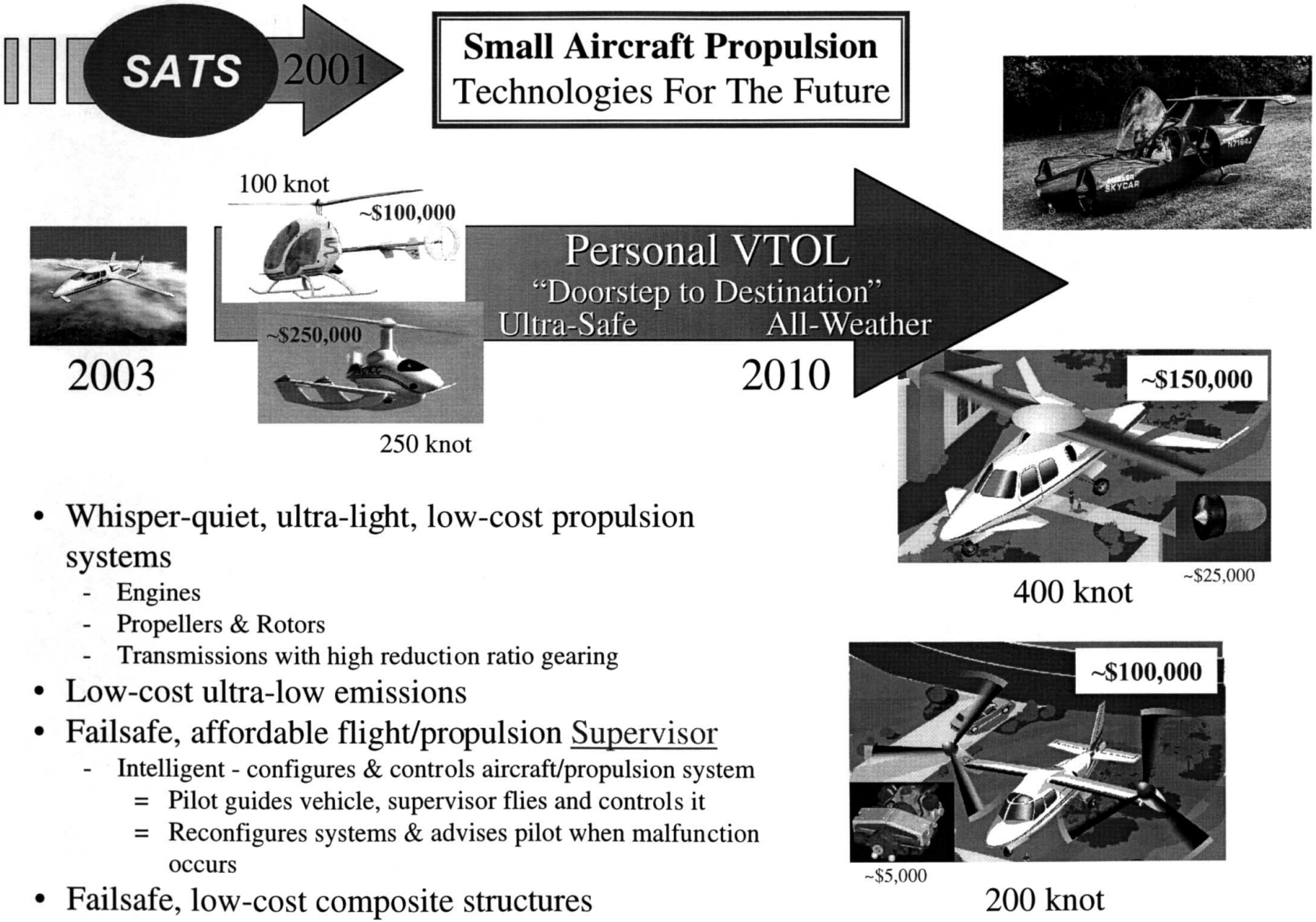


Combustor



Core Engine

GAP Project @ GRC



- Whisper-quiet, ultra-light, low-cost propulsion systems
  - Engines
  - Propellers & Rotors
  - Transmissions with high reduction ratio gearing
- Low-cost ultra-low emissions
- Failsafe, affordable flight/propulsion Supervisor
  - Intelligent - configures & controls aircraft/propulsion system
    - = Pilot guides vehicle, supervisor flies and controls it
    - = Reconfigures systems & advises pilot when malfunction occurs
- Failsafe, low-cost composite structures

SATS VTOL

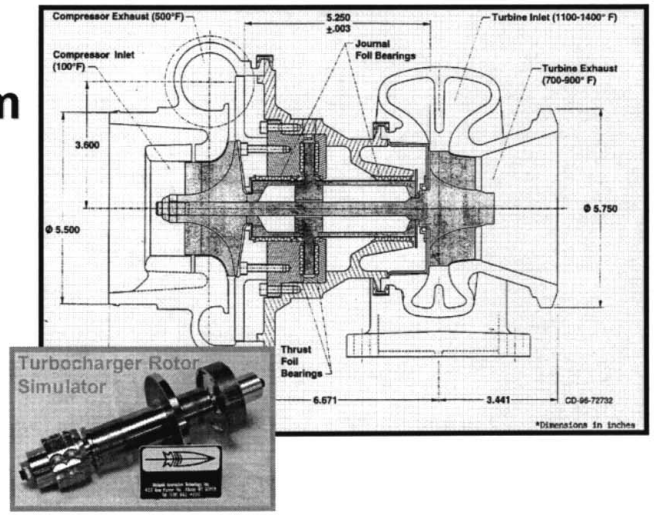
Future Plans:
Oil-Free Turbine Engine Project

Relevant Program

Oil-Free Turbocharger Status (Propulsion Base)

Accomplishments:

- **Rotor/bearings tested up to 121,500 rpm**
  (equivalent to 4.4 MDN)
- **Dynamic runout (orbit) < 1.0 mil**
  (5-8 mil typ. conventional oil lube turbo)
- **20 g shock loads**
- **Low Power Loss**
  (Estimated at 2 hp; 10 hp for typ. oil lube turbo)
- **Successful Gas Stand Test**
  (Full-speed, 95,000 rpm & Maximum Turbine Inlet Temperature, 1,200°F)



Remaining Activities:

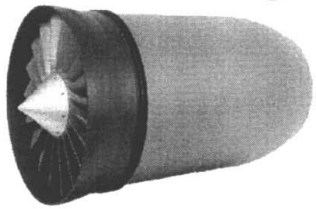
- **Turbocharger performance test on gas stand**
- **Engine performance test**
- **Engine emissions test (particulate)**

Glenn Research Center

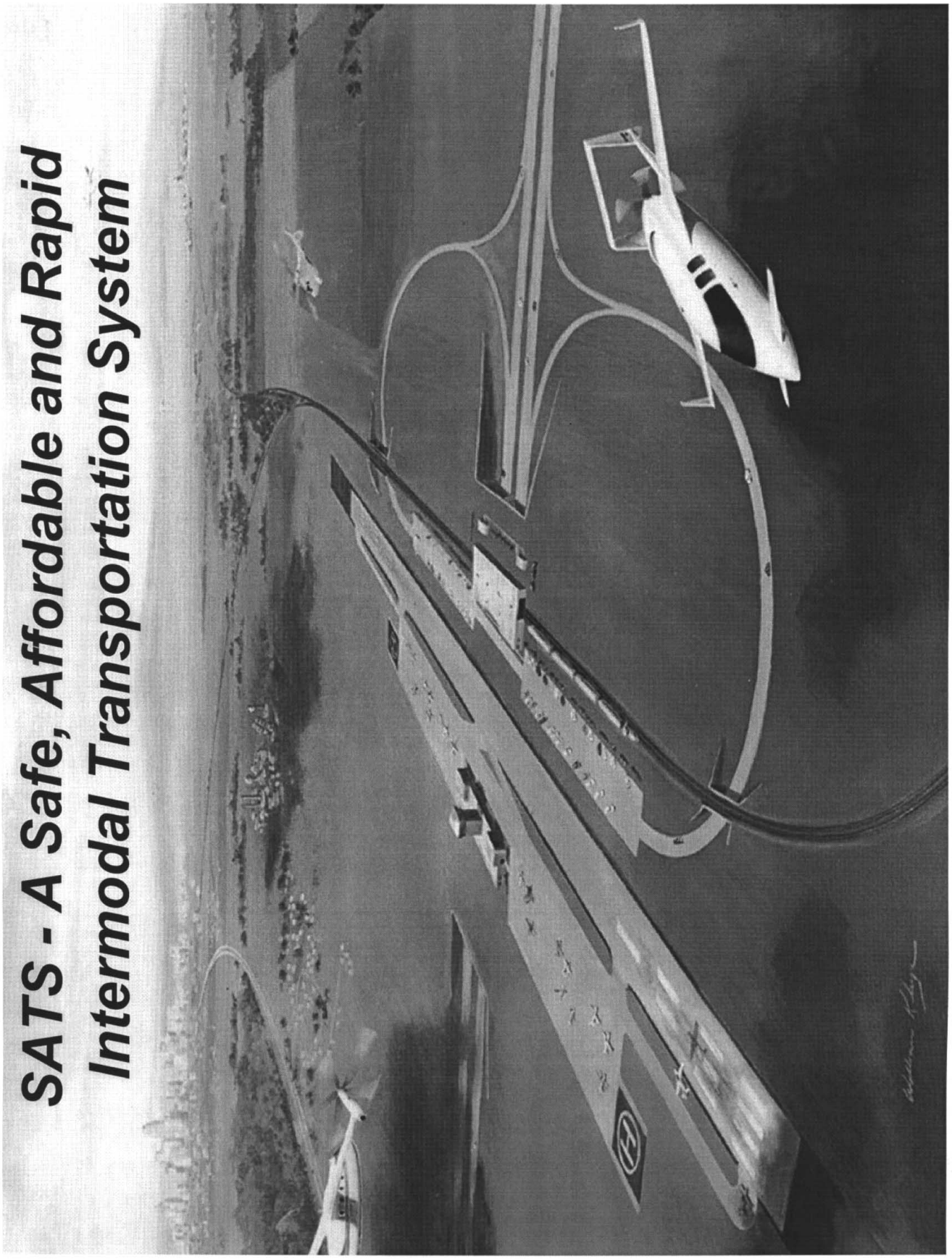
PROPULSION SYSTEMS BASE PROGRAM

AT

Oil-Free Turbine Engine Technology Project



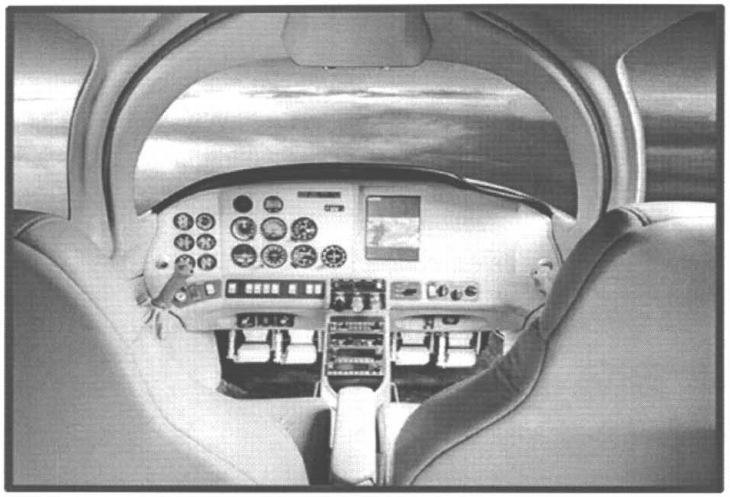
- Advance foil bearing design and analysis techniques
  - SOA foil bearing design and analysis is an art
  - Develop analytic capabilities to design and analyze bearings and shaft bearing systems
- Convert FJX-2 to oil-free operation and test engine
  - Develop foil bearing system for FJX-2 turbofan engine
    - > FJX-2 was designed to accommodate foil bearings
  - Incorporate, adapt and prove technologies developed for hot section foil bearings at GRC in turbine engine
  - Prepare for flight demonstration
- Transfer technology and lessons learned to US turbine engine industry
- Develop gear and bearing technologies for low-oil transmission
  - Provide a full scale demonstration of technologies


SATS - A Safe, Affordable and Rapid
Intermodal Transportation System

AGATE/GAP Usher In A New State of the Art

NASA Office of Aero-Space Technology

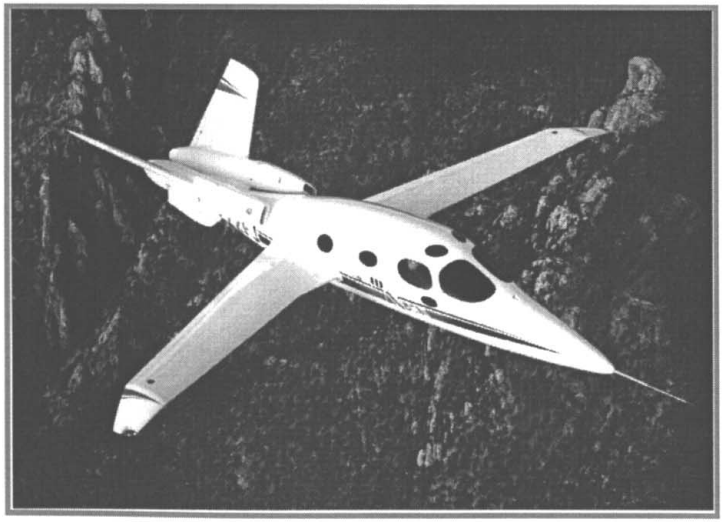
Safe Air Accessibility for Information Age Communities



Lancair Columbia 300

The New Generation Cockpits and Aircraft

Cirrus SR-20



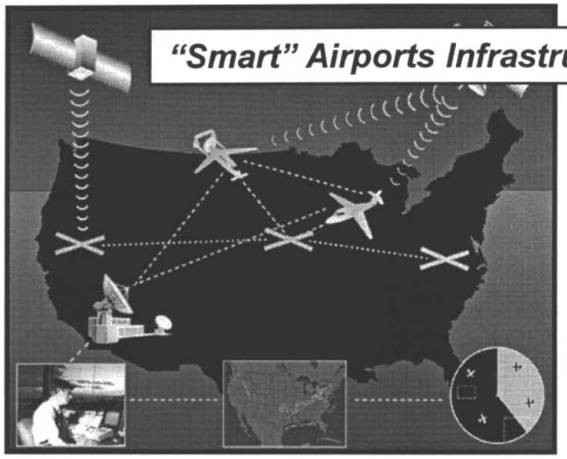
Williams V-Jet

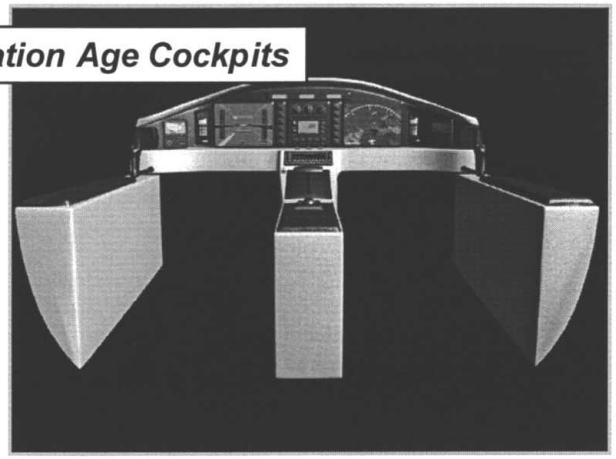
9

SATS Takes a System Approach to Transportation & Safety

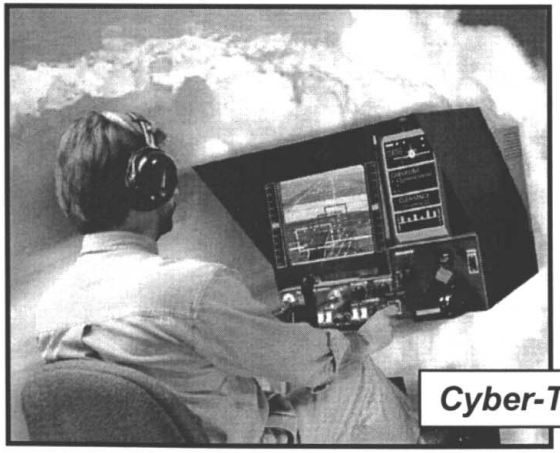
NASA Office of Aero-Space Technology

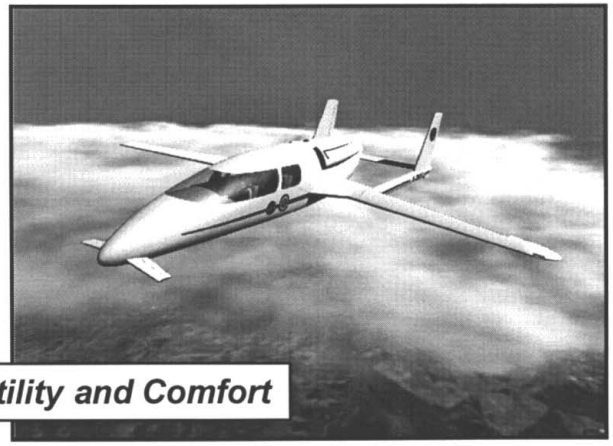
Safe Air Accessibility for Information Age Communities





An Integrated System Approach To Safety





Autoflight

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities

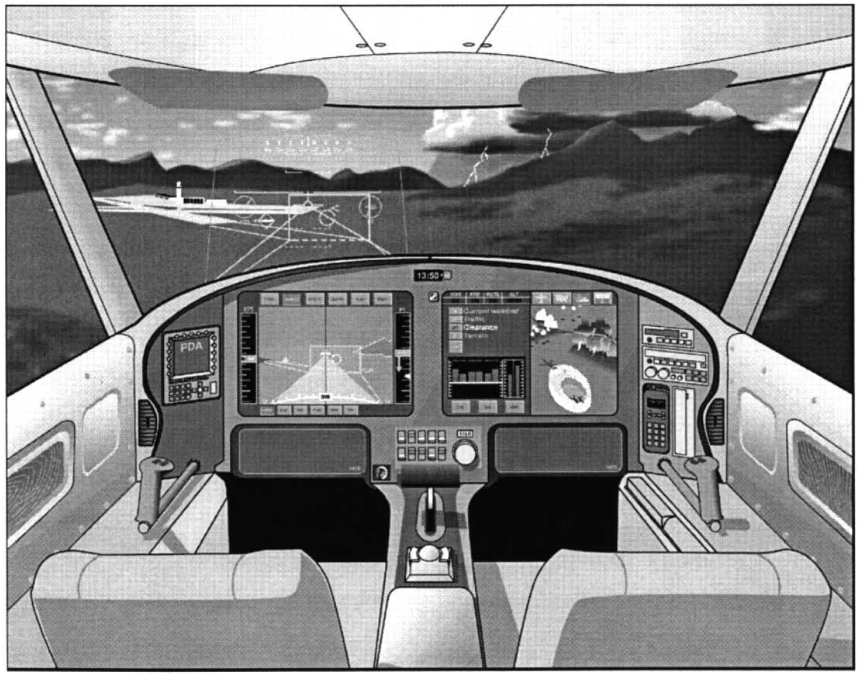
Reduce the complexity of aircraft control to car-like simplicity. Single-crew SATS aircraft operators will utilize simplified controls with automated assistance to navigate on virtual skyways. The objective is to achieve commercial aircraft levels of safety and navigational performance. The result will reduce cost and increase mission reliability for both hired-pilot and self-flown operations.

Features:

- Automatic intelligent controls which limit attitude & altitude excursions, and configures aircraft/propulsion for flight mode
- Safe operations by single-crew and lower-time users
- Abuse-tolerant controls
- Common interface across vehicles

Technologies:

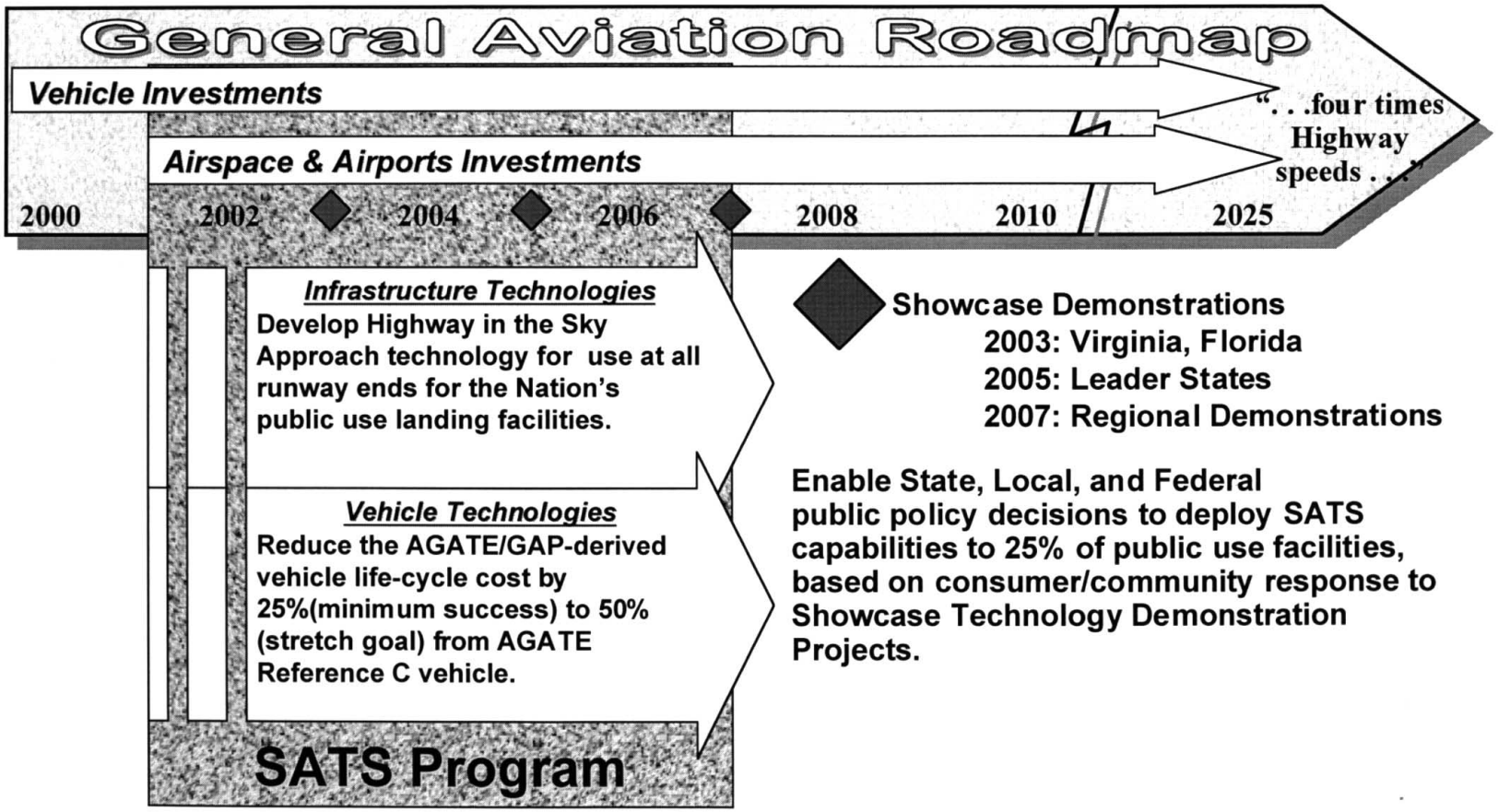
- Operator interface design and human/automation task allocation
- Automatic intelligent controls, health monitoring & guidance
- Decoupled controls
- Envelope protection
- Voice command



III A. SATS Program Description

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities



Ultra-Propulsion

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities

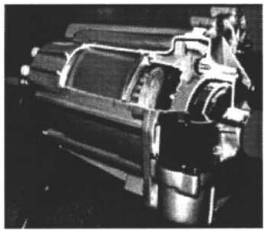
Whisper-quiet, maintenance-free, clean small engines and non-hydrocarbon-based propulsion technologies will result in imperceptible emissions and noise assuring passenger comfort and community acceptance of aircraft operations

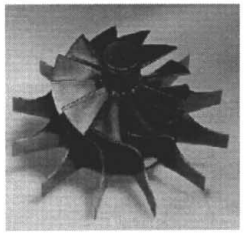
Features:

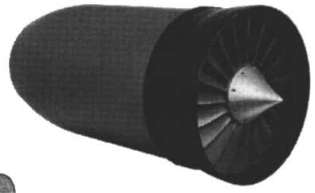
- Ultra-Safe
- Ultra-Reliable
- Automobile like ultra-affordability
- Assured community/customer acceptance

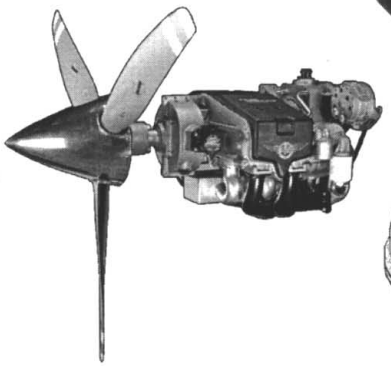
Technologies:

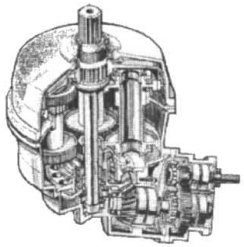
- Electric propulsion & non-hydrocarbon fuels
- Whisper-quiet engines, transmissions & propulsors
- Low-cost ultra-low emissions combustion
- Automated, intelligent, fail-safe, controls & health monitoring
- Simple, intuitive operator interface
- Failsafe, low-cost composite structures











"Smart" Landing Facilities

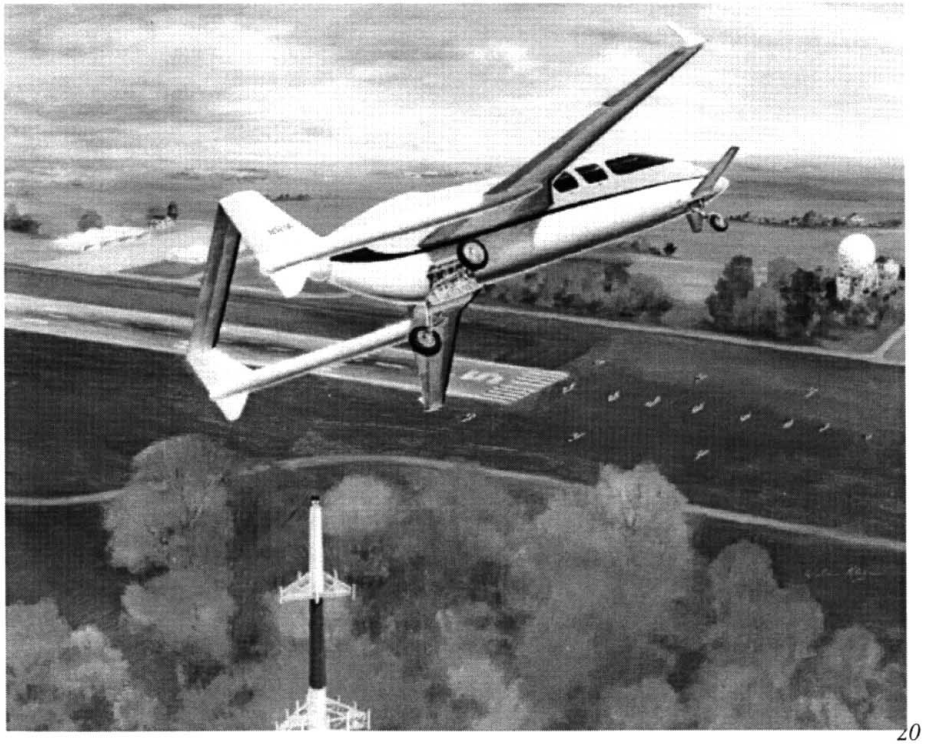
NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities

"Smart Landing Facilities" provide automation-enabled separation and sequencing in non-towered, non-radar, non-hub terminal airspace and simultaneous non-interfering operations for runway-independent aircraft at hubs. Landing facility information and status (runway lighting and condition) will be provided to airborne nodes (vehicles) by flight information service (FIS) including weather, traffic, flight plans, etc. while the commercial service (CIS) will provide maintenance, fueling, intermodal connection, and other information.

Functions:

- Aircraft separation and sequencing
- Real-time weather
- DGPS Corrections
- Maintenance, Repairs & Services
- Personalized Dispatch Services
- Intermodal Connectivity (ground & air)
- Food & Lodging Info.
- Recreation Info.

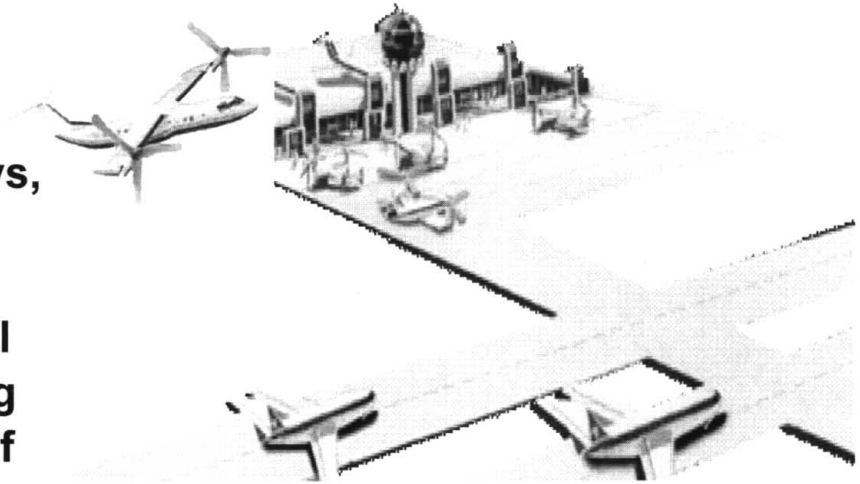


20

Runway Independent Aircraft Operations

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities



The Runway Independent Aircraft operations will increase hub & spoke airport throughput by using stub runways, taxiways, & vertiports instead of conventional runway under adverse weather conditions. Differential GPS will enable Simultaneous and Non-Interfering (SNI) operations possible independent of fixed wing traffic within the ATM System.

***Functions*:**

- Provide simultaneous and Non-Interfering hub airport operations including approach & departure paths independent of fixed wing traffic
- Seamless connectivity between hub and small landing facilities
- Low noise flight paths
- Stimulate development of future V/STOL & STOL aircraft

Affordable Manufacturing

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities

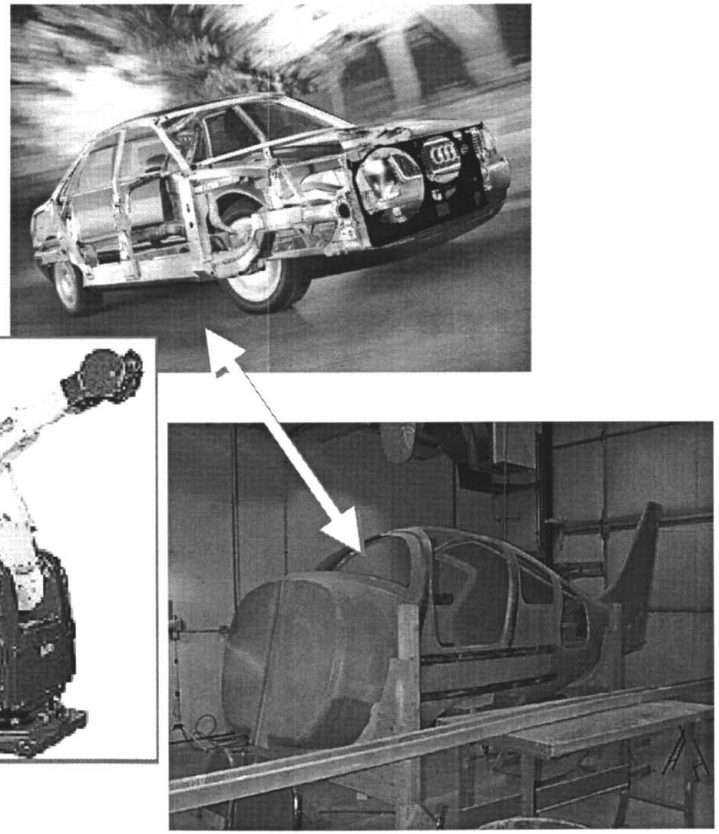
Low-cost manufacturing to integrate safety-enabling technologies at costs 25% (minimum success requirement) to 50% (goal success requirement) less than AGATE/GAP Reference C aircraft baseline

Features:

- High-volume lean production
- Minimal hand labor (robotic labor)
- Certification integral to design & manufacturing processes
- Automotive safety technologies (air-bags, energy-absorbing structures, etc.)

Technologies:

- Robotic manufacturing
- Composite material systems
- Component-level certification reform
- Integrated ice & lightning protection



22

Cyber-Tutor Training

NASA Office of Aero-Space Technology

Safe Air Accessibility for Information Age Communities

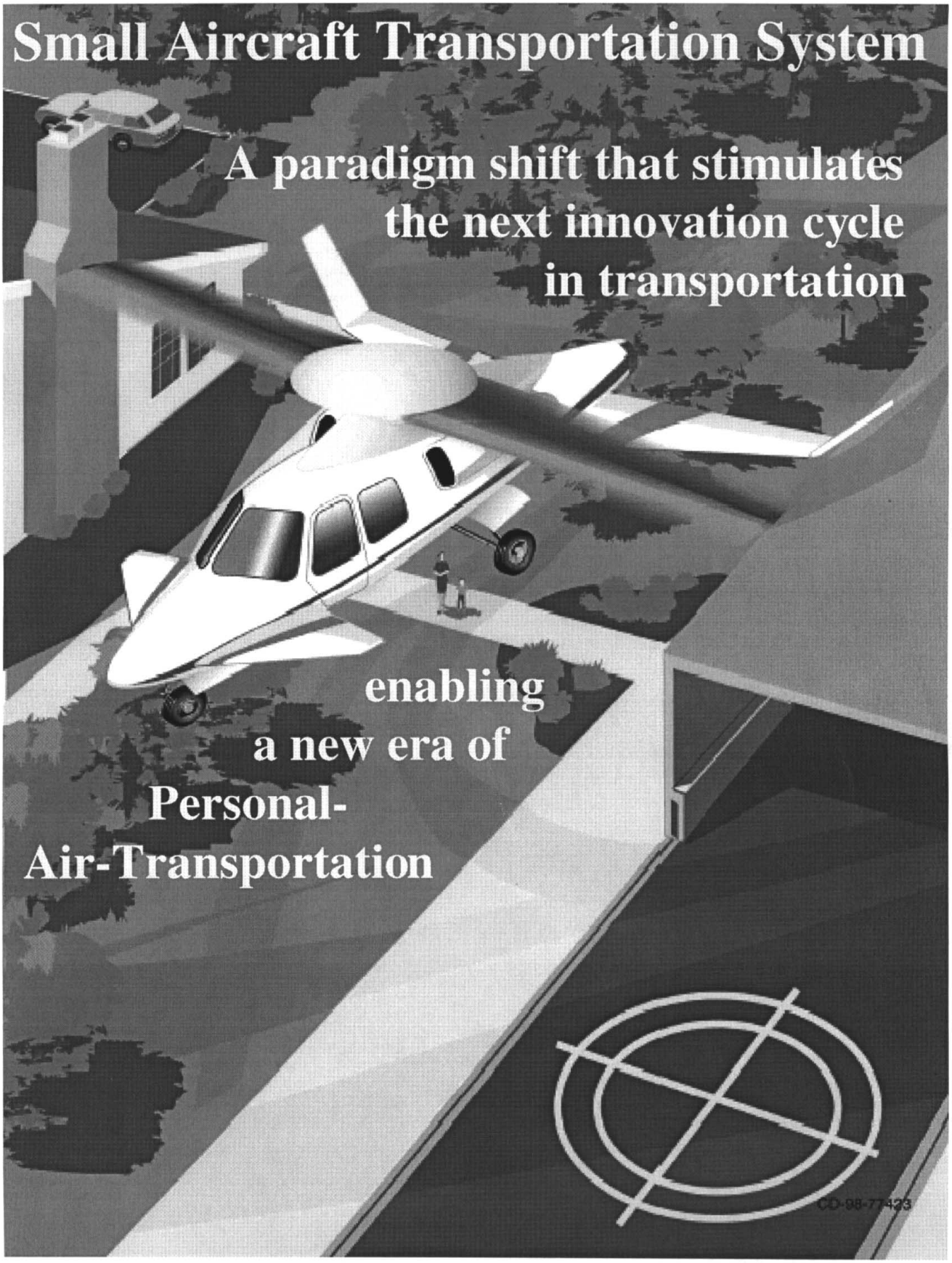
Integrate advanced training technologies to reduce training time & cost to obtain and maintain all-weather safe flying skills. Reduce training cost and calendar time by 50% from present standards

Features:

- Unified Instrument-Private Curriculum for Highways in the Sky Systems
- Hazardous weather avoidance
- Emergency and abnormal operating procedures in AGATE-derived aircraft
- Turbojet pilot training for GAP-powered aircraft

Technologies:

- Lower-cost, higher-fidelity simulation
- Self-training capability
- Onboard, embedded training
- Web-based learning
- Computer-based training


Small Aircraft Transportation System
A paradigm shift that stimulates
the next innovation cycle
in transportation
enabling
a new era of
Personal-
Air-Transportation
CD-98-77423