Short Field Take-Off and Landing Performance as an Enabling Technology for a Greener, More Efficient Airspace System

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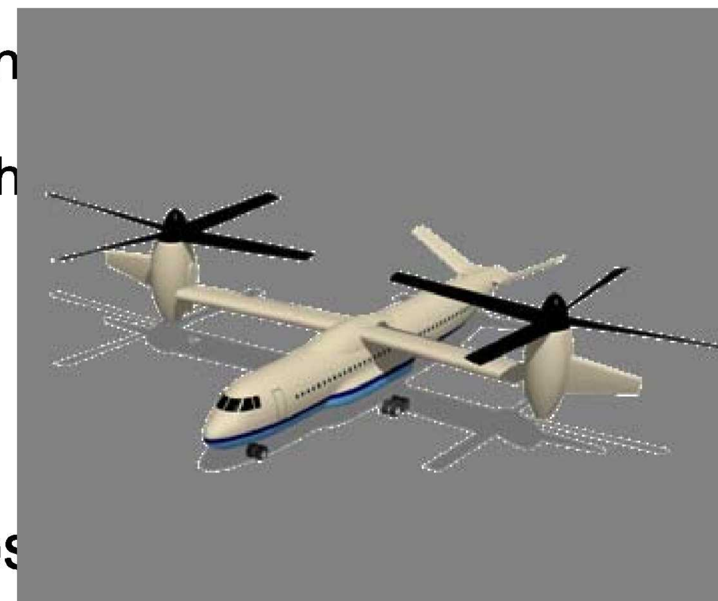
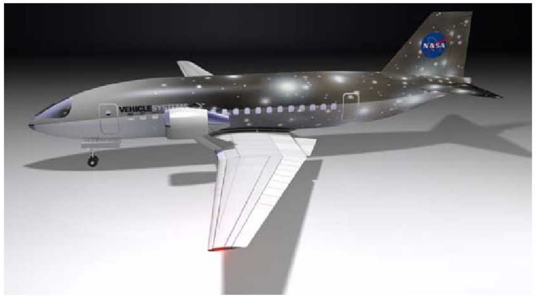
CESTOL & CTR

- CESTOL - Cruise Efficient Short Take-Off and Landing
  - Fixed wing aircraft
  - 3000’ field length
  - Mach > 0.8 in cruise
- CTR – Civil Tilt Rotor
  - Rotary wing aircraft
  - Hover out-of-ground effect, one engin inoperative
  - ~1500’ “protection” zone on approach and departure
  - 300 – 350 knot cruise performance
- Goal - Expand and optimize the number of take-off and landing “locations” available to get passengers and cargo moved mos efficiently for the entire system



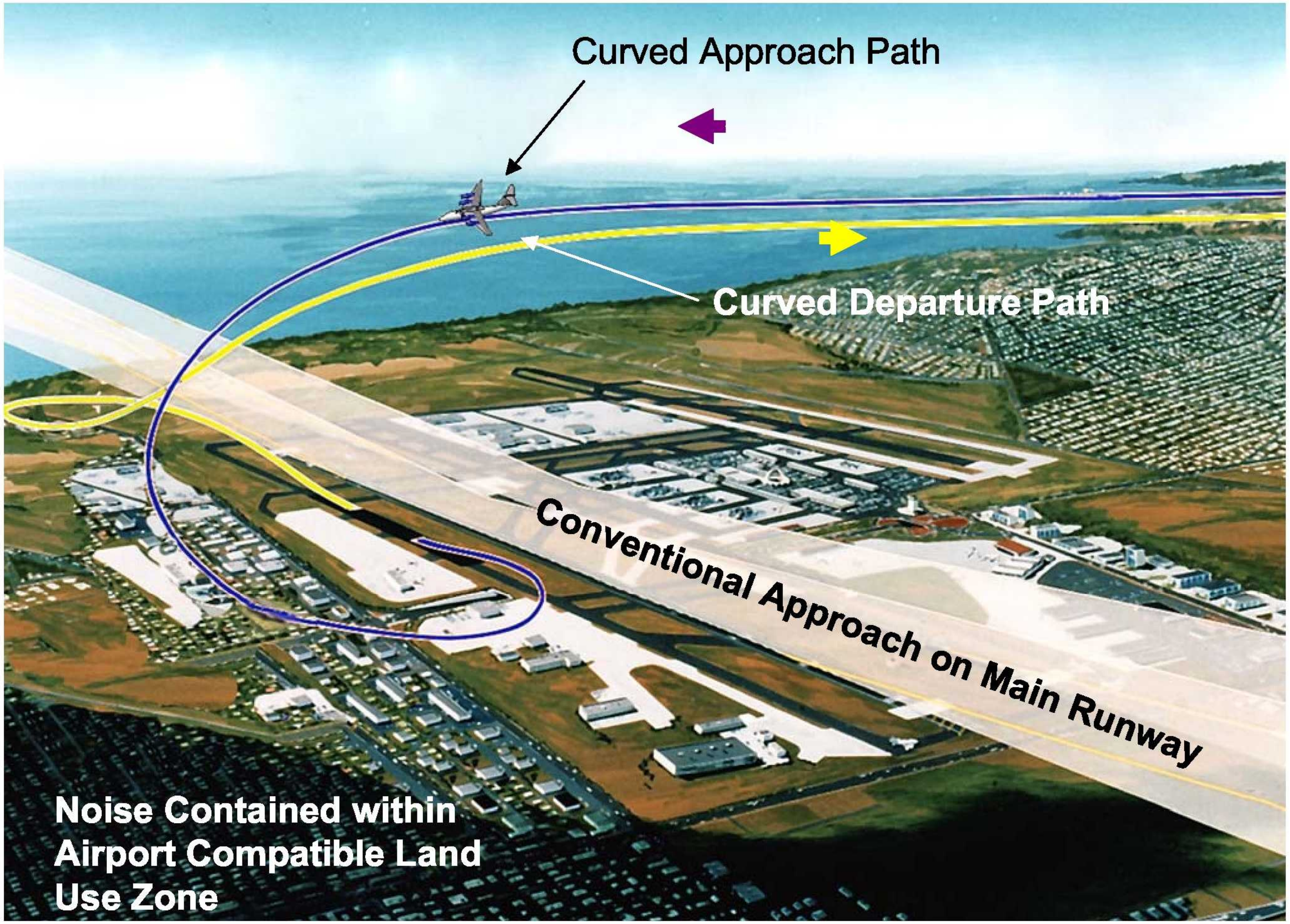
Short Take-Off and Landing Field Length Flexibility

- The STOL runway or vertiport needs to be unused, or under-utilized to increase the number of operations at an impacted airport
  - The main traffic must still flow unimpeded
- The STOL aircraft needs to operate in the terminal area in a simultaneous non-interfering (SNI) manner with the conventional traffic by using high maneuverability associated with low-speed flight, and steep glide slopes
  - The main traffic must still flow unimpeded
- Eventually STOL capability opens up unused airports, especially those in the "metroplex". This has the potential to relieve the hubs when they reach saturation.
  - However, the market need for service at those airports and the airline's willingness to leave the hub will determine the utility of those satellite airports
  - The main traffic must still flow unimpeded (note repeated emphasis on this bullet)



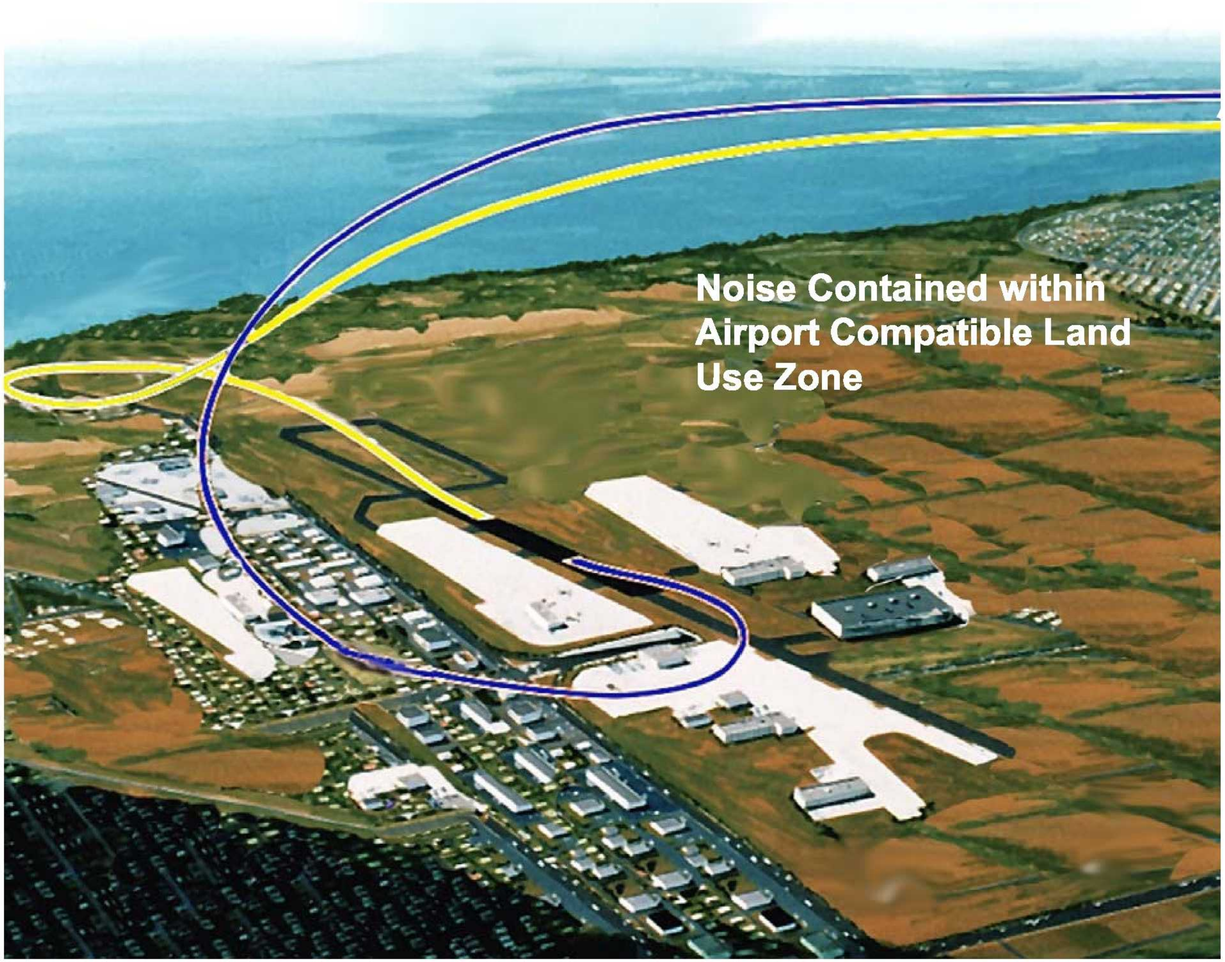
CESTOL / CTR Serves the Major, Delay Impacted Hub Airports

Simultaneous & Non-Interfering (SNI) Operations



The STOL / CTR aircraft avoids the airspace and runways needed by the conventional traffic

CESTOL / CTR Reaches Out to the Satellite Airports



The STOL / CTR aircraft opens up the satellite airports in the "Metroplex" without disturbing the communities that have been undisturbed in the past

Short Field Aircraft Potential for Airspace Capacity and Throughput Improvements

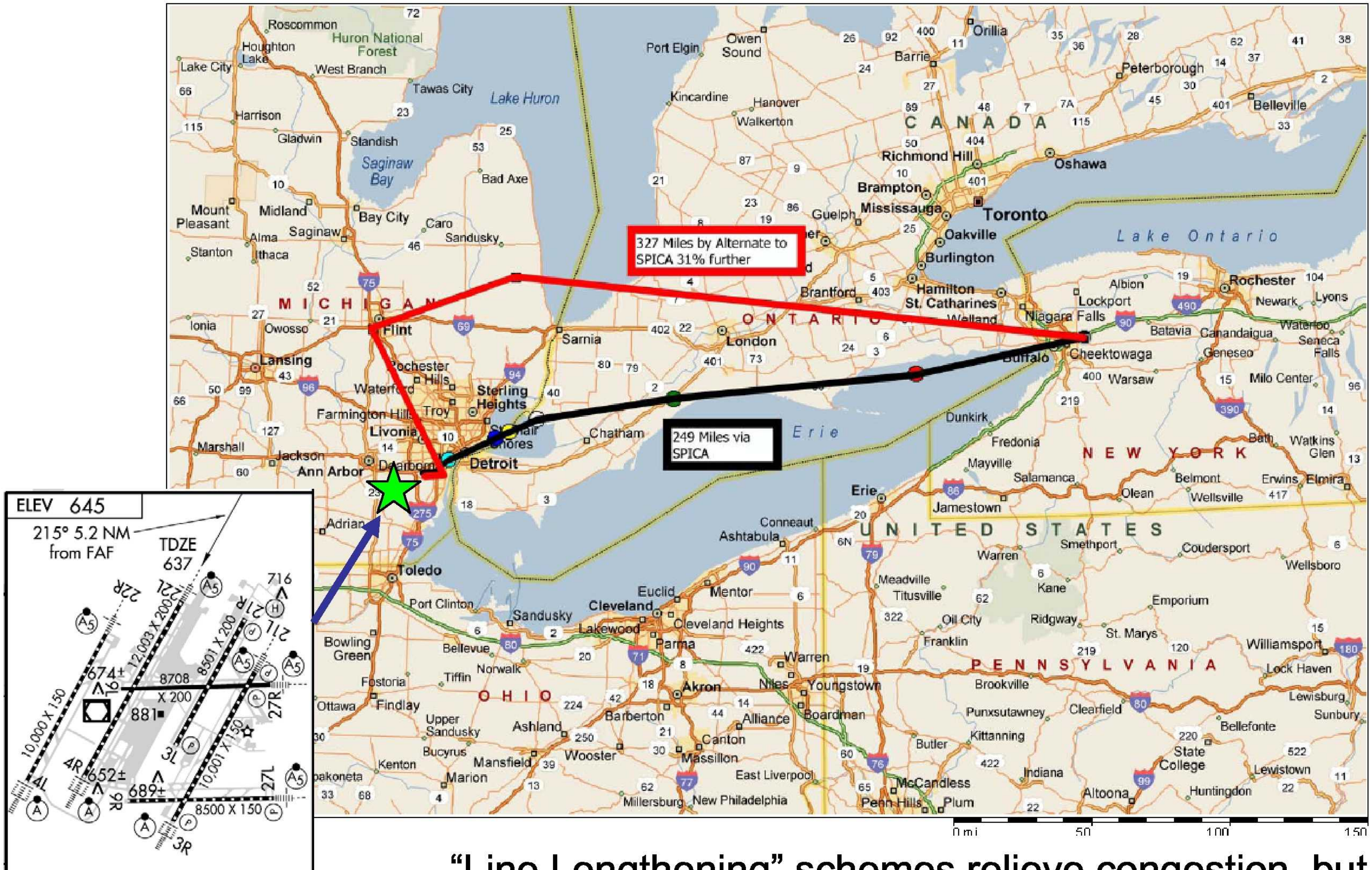
- Both CESTOL and CTR aircraft are being studied in the context of improving airspace capacity and throughput
- CESTOL
  - E.g., Sensis study (Couluris, et al) examining under-utilized airports
  - Ongoing "Advanced Vehicles in Next Gen" Airspace Systems NRA project (led by Sensis and Honeywell)
- CTR
  - Ongoing "Advanced Vehicles in Next Gen" Airspace Systems NRA project (led by Sensis)
  - Ongoing "CTR in Next Gen" SRW-sponsored project (led by SAIC)
- The above airspace studies are also performing estimates of noise and emissions, to varying degrees of fidelity
- There are challenges and opportunities for reducing systemic environmental impact of aviation though use of short field aircraft

Improvements to Capacity & Efficiency as a Mechanism for Greener Aviation

- Greater System Capacity Means Reducing Delays, This Saves on Wasted Fuel
  – Reducing idling & ground holds waiting for the take-off runway or a destination landing slot
  – Reducing enroute holding patterns waiting for the landing runway
  – Reduce lengthening the route implemented to facilitate aircraft spacing or slowing the aircraft down
    - Detroit STAR example on next slide
  – Optimizing the whole system to use less fuel, not just one part, component, or aircraft type
    - Newark study example

From the “FAA Severe Weather / Impacted Airport and Airspace” Playbook, DTW – Spica 2 Arrival

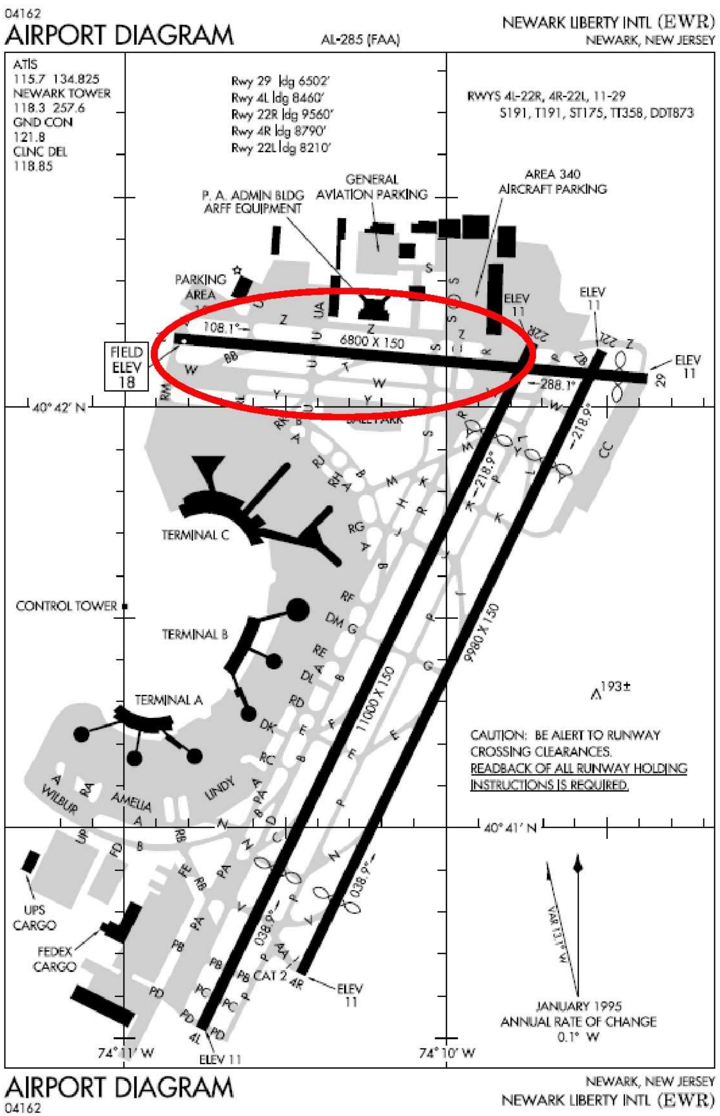
DTW



“Line Lengthening” schemes relieve congestion, but burn more fuel

Underutilized Runway Example - Newark Liberty International R 11/29

- CESTOL assumed to use RWY 11 for arrivals and turboprop arrival routes to the runway
- CESTOL use the western half of RWY 11, up to 4000 foot well short of RWY 4L
- CESTOL departures on 4/22 runways with other traffic
- Study by Sensis (Couluris, et al) estimates 19.6% reduction in delay for a typical day in 2016 when propagated across the NAS and other 33 OEP airports
  - Converted to fuel savings, rough estimates of 200M – 300M gallons per year of fuel saved

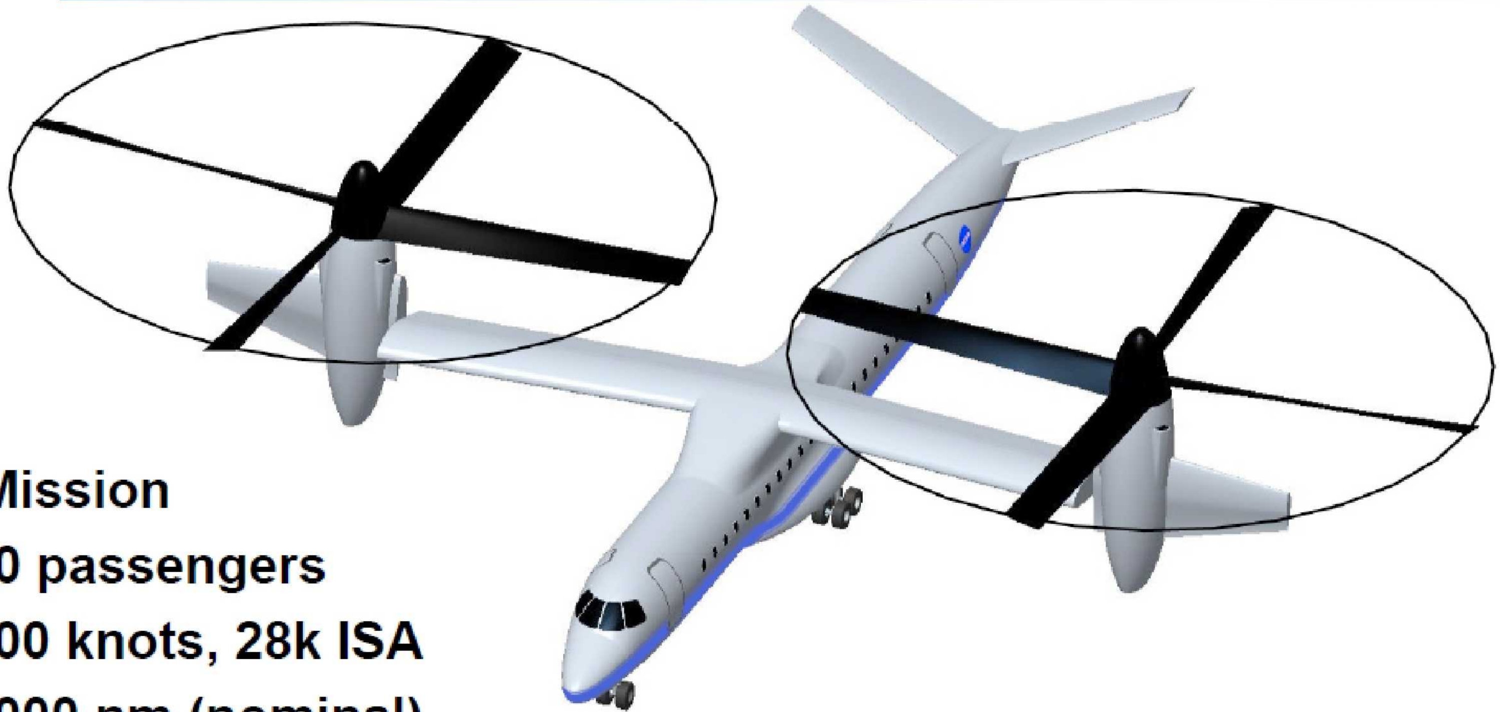


The CESTOL - More than Just Short Field Performance

- High-speed cruise (M ≈ 0.8, alt 30K)
  - Fuel burn and emissions are driven by the cruise performance
  - Jet transport - transcontinental capability, although nominally sized for “regional” missions
  - Avoid weather problems at lower altitudes
  - Does not become the bottleneck on the airways by flying too slow

- This capability is deemed critical enough to use acronym CESTOL – Cruise Efficient Short Take-Off and Landing

CTR - Payload & Efficiency



Mission

Payload: **90 passengers**

Cruise: **300 knots, 28k ISA**

Range: **1000 nm (nominal)**

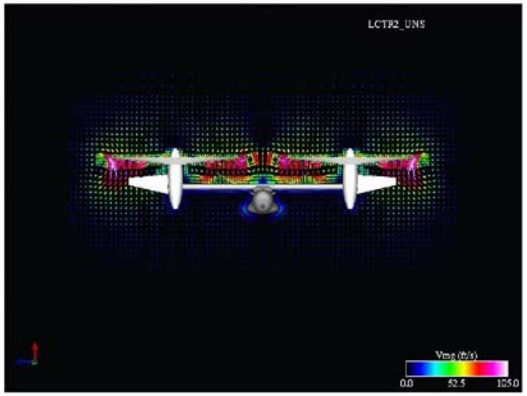
- Technical Challenges
  - Large payloads
  - Hover with one engine inoperative
  - High cruise speed (relative to current rotorcraft)
  - Active rotor controls
  - Advanced flight dynamics & control systems
  - Larger, slower rotors to reduce noise
  - Variable speed and high torque drive systems

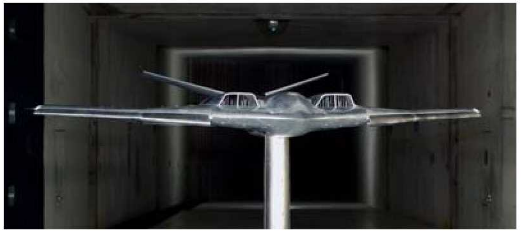
Some Technology Issues to Overcome for Implementing Short-Field, Powered-Lift Capability

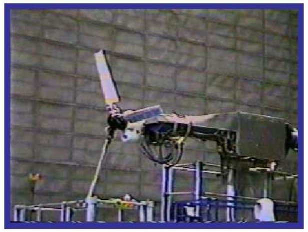
- **Airframe related issues for rotor or jet-powered lift aircraft compared to typical conventional take-off and landing aircraft**
  - Higher thrust to weight ratio
  - Lower wing loading
  - Higher specific fuel consumption
  - Higher drag
  - Higher local noise levels
  - Cruise efficiency impacted by low-speed performance requirements
  - Heavy, complex mechanisms to generate lift
  - Controlling it – Pilot / airframe integration and workload
- **Operational issues with rotor or jet-powered lift aircraft in the system**
  - Deviations from standard approaches and departures in TRACON airspace
  - Sharing of airspace in unconventional manner
  - Tailwind, crosswind operations
  - Crossing runways, sharing runways, land and hold short operations
  - Local downwash and wake vortices in the terminal area

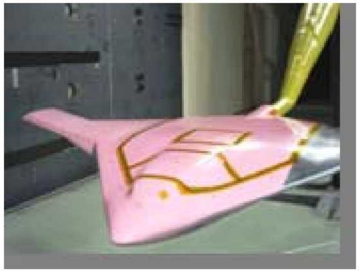
Some Ways to Overcome the Technology Challenges Associated with Short-Field, Powered-Lift Capability

- Airframe
  - Unconventional design such as Hybrid Wing Body (HWB) to reduce drag
  - Engine / airframe integration technology
  - Active flow control / circulation control
  - Flow separation control
  - Variable geometry rotor blade technology
  - Improved structural efficiency
  - Noise shielding, reduction, and treatment
  - Higher Bypass Ratio Engines / Larger Rotors
    - Slower propulsive thrust is quieter, more fuel efficient
  - Variable Cycle Engines / Variable Speed Transmissions
    - Greater efficiency for generating lift and forward cruise propulsion with same engines









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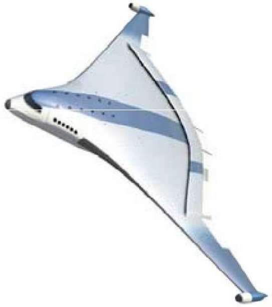
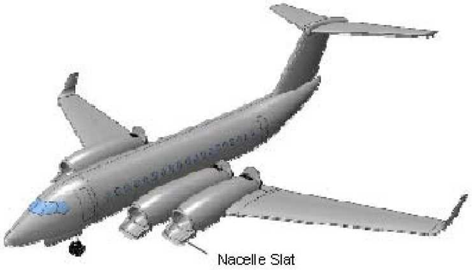
Some Ways to Overcome the Technology Challenges Associated with Short-Field, Powered-Lift Capability

- Operations
  - Improved Required Navigation Performance (RNP) (0.3 nm current, 0.05 nm optimal for 65 – 85 knots maneuver speed)
  - Steep & spiral descent and departures over the airport property to reduce community noise (Noise attenuation with distance)
  - Improved ground movement and handling techniques
    - Reduce time on the ground
    - Reduce distance traveled on the ground
  - Schedule optimizing





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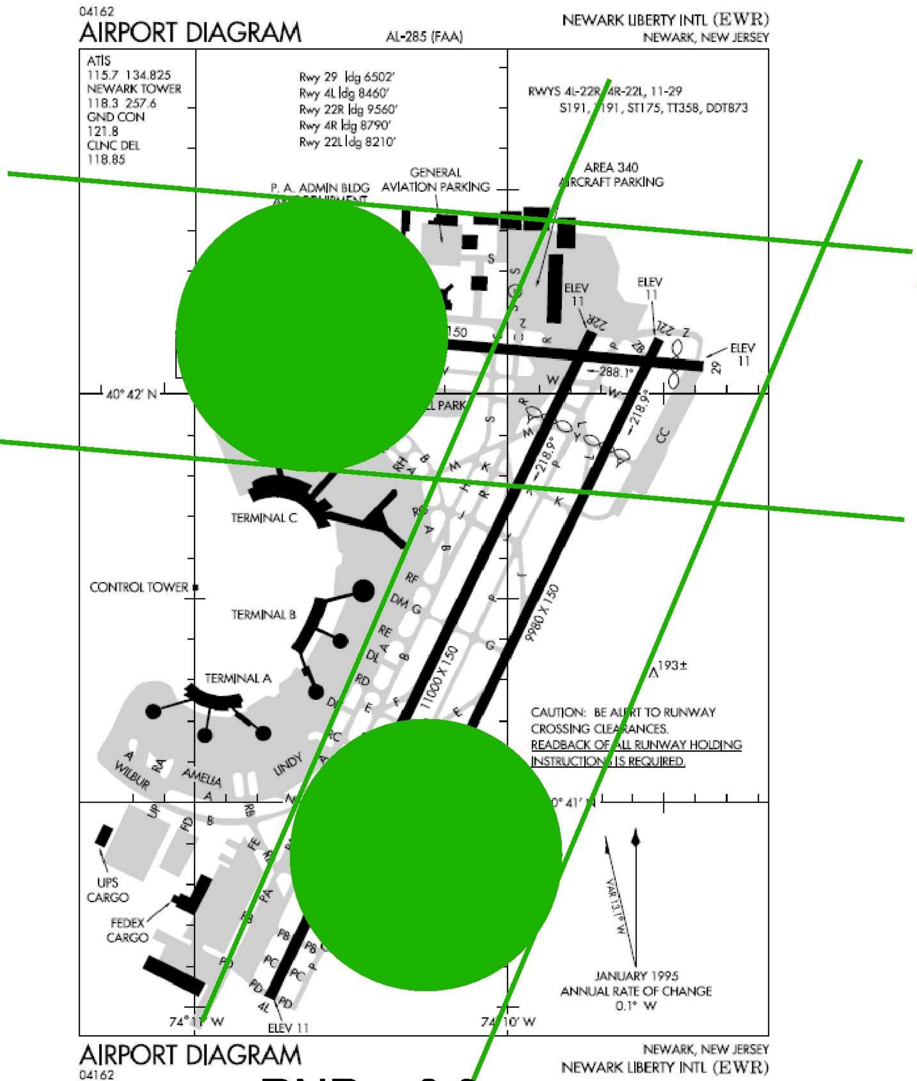
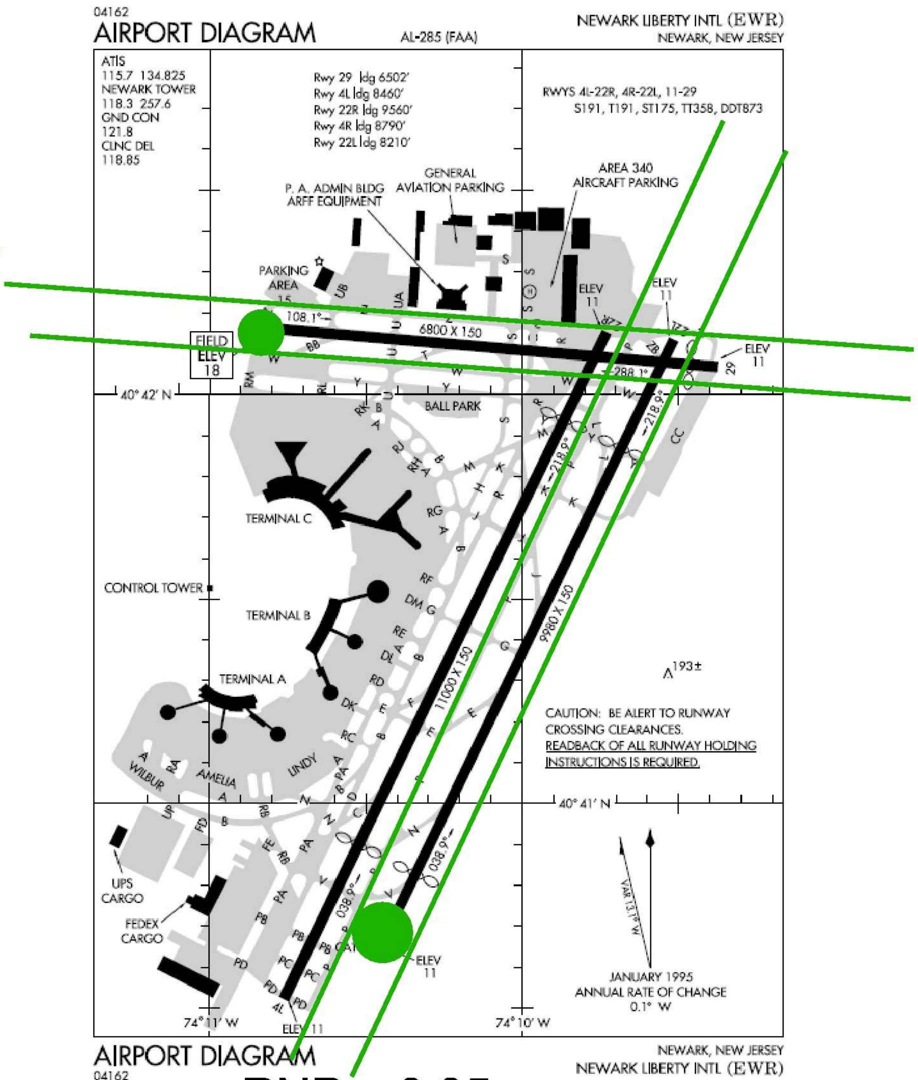
Improvements in RNP will facilitate the Simultaneous Non – Interfering Operations

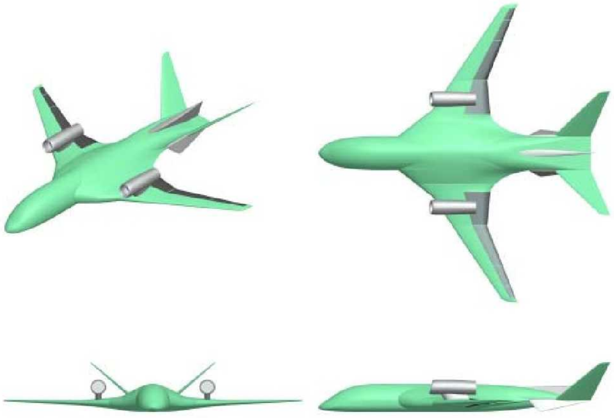


RNP = 0.3 nm



RNP = 0.05 nm

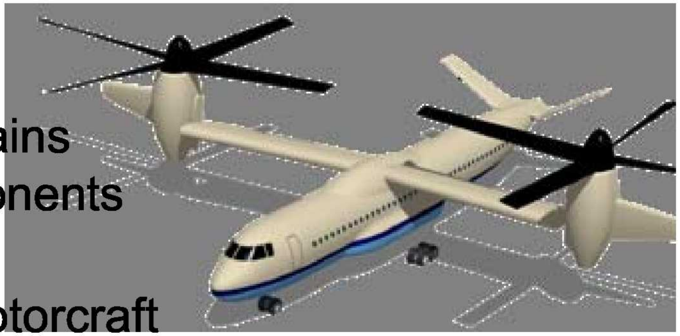
Some of the Subsonic Fixed Wing Project's (SFW) Efforts to Develop CESTOL Technology



- **Aerodynamics**
  - Active high lift, circulation control
  - Separated flow control
  - CFD of powered lift systems
  - Wind tunnel tests of ESTOL configurations
- **Controls & Dynamics**
  - Intelligent control research for CESTOL
  - CESTOL extended flight envelope & complex control effectors challenges
  - Integrated Flight-Propulsion Control
- **Acoustics**
  - Quantification and reductions of noise generated by high-lift systems
  - Acoustics of high bypass ratio propulsion systems
- **CESTOL Partnership Activities**
  - AFRL / Industry Dual Use Studies
  - CESTOL business case study
  - NRA with Cal Poly / GTRI for CESTOL Aerodynamics and Acoustics
  - More Electric Airplane

Some of the Subsonic Rotary Wing Project's (SRW) Efforts to Develop CTR Technology

- **Aeromechanics**
  - Innovative vehicle configurations
  - Improved design tools/methodologies
  - Active rotor control approaches of several different types
- **Acoustics**
  - Improved passenger and community acceptance via various noise and vibration reduction approaches
  - Optimized flight profiles for low-noise operation
  - Cabin noise attenuation with minimal weight penalty
  - Low-frequency noise effects
- **Structures & Materials**
  - High-temperature materials for engine efficiency improvements
  - Tailored structures for acoustic and vibration attenuation
- **Propulsion**
  - Variable speed rotor systems
  - Low-speed, high-torque transmissions/drive trains
  - Improved efficiency turbo-shaft engines/components
- **Flight Dynamics and Control**
  - Handling qualities assessment for very large rotorcraft
  - Advanced tools/devices for active rotor/flow control



Conclusions

- **Short field length capable aircraft can be used to increase capacity and reduce delays within the Next Generation Airspace System**
  - Use runways, vertiports, and airspace more efficiently

- **Performance penalties associated with short-field capability needs to be mitigated with technology**
  - Then compared with conventional take-off and landing green aircraft to determine delay reductions, and the associated fuel savings that come with those reductions

- **The green benefit to short field performance is based on a system wide answer.**
  - Individual powered-lift aircraft may actually burn more fuel than their conventional counterparts, but if the system becomes more efficient by using those aircraft in strategic locations at strategic times, the net result may be fuel saved