The Coming Convergence Between Manned and Unmanned Aviation

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Committee on Autonomy Research for Civil Aviation
Thanks to…

- Bruce Holmes
- Brent Wouters
- Ella Atkins
A word about the UAV market…

- Some UAS markets are real:
  - ISR
  - Science
  - Small UAS

- But skeptical on whether today’s paradigm really has broad applications within the NAS

- To do that, you must move to the next stage of the UAS revolution – towards UAS that carry passengers
UAS Uses evolve

- Data collection and relay
- Air-to-ground weapons delivery
- Cargo delivery
- Air-to-air
- Passenger carriage
  - Casualty Extraction
  - Special Missions
  - General aviation
Evolution of Transportation Demand

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)

High-Speed Transport in 2020 – as large as all transport in 1960 and as all auto transport in 1990

- **Auto**: 20%, 9%, 6%
- **Bus**: 3%, 9%, 25%
- **Rail**: 23%, 9%, 43%
- **High-Speed Transport**: 54%, 53%, 26%

- 1960: 5.5 Trillion pass-km
- 1990: 23.4 Trillion pass-km
- 2020: 53 Trillion pass-km
General Aviation Not Growing With GDP Due to Poor Technology and Lack of Profitability

Data illustrate decoupling of demand from GDP, indicating that new strategies are required to move this market’s needle.
....also fewer pilots
Why?

• Most important concerns of potential new GA buyer:
  ➢ Safety (am I going to die if I fly in this?)
  ➢ Safety (am I going to die if I try to fly it myself?)
  ➢ Safety (will my family die if I take them along?)

• Cost & complexity to remain current in today’s ATC environment

• Modern GA aircraft (Cirrus, Diamond, etc) have exploited composites, aerodynamics, propulsion, and glass cockpits
  ➢ Without fundamental changes in safety record
  ➢ Without reversal of general trend of decline
Hypothesis

- Reversing decline of General Aviation can come only by incorporating technologies currently emerging from “unmanned” aviation
- Not really a question of manned versus unmanned, but rather where on the spectrum of autonomy one falls…
  - Between no automation and full automation

AGATE Alliance
1994-2001

GAP Project
1995-2000

ERAST
1994-2002

SATS Project
2001-2005

Outcome: Technology, Regulatory Policy, Infrastructure Investment supporting expanded use of community airports and smaller aircraft for public transportation; however, we did not go far enough.

UAS in the NAS
2011-2016
Aurora Flight Sciences

SATS Assessment

• Deployed new transportation system demand analytical modeling.
• Conducted Business Case studies for:
  – North Carolina
  – Ohio
  – Upper Great Plains
  – Virginia
  – Michigan
  – Northeast Corridor & the Southeast
• Result
  – At $1.50 - $2.00/seat-mile operators earn 20% profit
  – There is sufficient demand at those fares to support sizable fleets of aircraft
• However: Purpose-designed aircraft are needed to achieve fares ~< $1/seat-mile
The DayJet Experience

- Command Center Ops
  - 50% fewer dispatchers
  - Basis for automation/OPA
- ~ 1 year of revenue ops
- 28 aircraft
- 4.5 pilots/aircraft
- 61 DayPorts; 375 cities total
- Hard to model U.S. demand in 2007; now possible to do the nation
- FAA Kudos

Out of 400 million U.S. business trips/year, our ABM projected capturing between 1.5 – 2% with Dayjet business model, depending on regions and consumer behaviors. At 1.5% of market, 6 million legs flown requires 1500-2000 aircraft flying 10 legs per day per aircraft.
A DayJet Lesson on Aircraft

11 months of revenue service
- Average Trip Length = 252 nm
- Shortest leg – 97 nm
- Longest leg – 450 nm
- Typical Altitude = FL 180-210
- $1.25/seat-mile < Fares < $4/s-m

Eclipse 500
- Max Range = 1100 nm
- Optimum Cruise Altitudes – FL 350-410

SATSAir Story Very Similar (Cirrus SR 22, 4 years service)
Medium Term Market Driver: Scheduled Air Service Contraction

Based on data from the US Department of Transportation, Bureau of Transportation Statistics.

The continuing contraction of the scheduled air carrier industry creates a market vacuum as communities lose service.
Enablers for Innovation in On-Demand Air Carrier Service

The “Right” Airplane

Real-time Logistics

Small World Networks

OPA and NextGen

The regulatory, technical, and operational needs converge for UAS and On-Demand air service and OPA accelerates the opportunity

OPA reduces crew costs by half (~15% of op. ex.)
NextGen reduces fuel costs by 5 – 15% (estimates during FAA Test Bed project)
Hence the “Optionally Piloted Aircraft”

- Essentially, a UAV with a human onboard as the “see and avoid” sensor

- Affordable
- Quiet
- Flexible
  - Manned
  - Unmanned
  - Hybrid
- High Performance
How Centaur works today

STANAG 4586
The controls
Centaur OPA Concept of Employment

1. Centaur is flown to mission site with a two-person crew
   - OPA/UAS avionics inactive and carried onboard
   - Ground control station and LOS GDT carried in pelican cases
2. Crew converts Centaur to a UAS and performs pre-flight checks
3. Unmanned mission operations
4. Crew converts Centaur to a manned aircraft and performs pre-flight
5. Centaur is flown from mission site in unrestricted airspace

Optional BLOS C2 and/or Payload Data Backhaul

Local C2 from GCS and Payload Data Exploitation (GCS and RVTs)
## Roadmap

<table>
<thead>
<tr>
<th>Version</th>
<th>Market</th>
<th>Market Size</th>
<th>Certification</th>
<th>Network/C^3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Centaur I</strong></td>
<td>• ISR &amp; Com Relay</td>
<td>Tens-hundreds (10^1-10^2)</td>
<td>Certified in manned mode</td>
<td>Dedicated GCS</td>
</tr>
<tr>
<td>TODAY</td>
<td>• Science Research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Airspace R&amp;D</td>
<td></td>
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</tr>
<tr>
<td><strong>Centaur II</strong></td>
<td>• Cargo delivery</td>
<td>Hundreds-thousands (10^2-10^3)</td>
<td>Certified for single-pilot ops w/ PX &amp; UAV flight in NAS w/o PX</td>
<td>Fleet dispatch center</td>
</tr>
<tr>
<td>3-5 years</td>
<td>• Air taxi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Centaur III</strong></td>
<td>• Personal transportation</td>
<td>Thousands-tens of thousands (10^3-10^4)</td>
<td>Certified for UAV flight in NAS with passengers</td>
<td>Network operations center</td>
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<tr>
<td>7-10 years</td>
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</tbody>
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Fundamental question: who is in charge?

<table>
<thead>
<tr>
<th>Nominal</th>
<th>Emergency</th>
<th>Example</th>
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<tbody>
<tr>
<td>Human</td>
<td>Human</td>
<td>JB191</td>
</tr>
<tr>
<td>Computer</td>
<td>Human</td>
<td>AF447</td>
</tr>
<tr>
<td>Human</td>
<td>Computer</td>
<td>US1549/Atkins</td>
</tr>
<tr>
<td>Computer</td>
<td>Computer</td>
<td></td>
</tr>
</tbody>
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Figure 16: AFP Landing Trajectory to LGA 22 (3D): Loss-of-thrust detection + 12 seconds.
Summary

• Decline of General Aviation cannot be reversed without major injection of technology to mask complexity and improve the user experience

• This technology is emerging from a variety of sources
  ➢ NEXTGEN
  ➢ NASA Systems Programs
  ➢ UAS

• Winners in this market will be those who successfully integrate these trends

• *Not an issue of “manned” versus “unmanned” but where on the spectrum of automation you fall*
Where should the government focus?

- Certification issues – how will new systems be certified?
- Human-machine interface
  - What reversionary modes should exist?
  - Nominal and emergency conditions
- Network issues
  - I can build the iPhone, but who will build the network?
  - Need secure, digital data links for command and control
  - ADS-B for system-wide traffic separation & collision avoidance