Onboard Pilot Decision Aid for High Volume Operations in Self-controlled Airspace

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Overview

- New Challenges and Issues
  - Small Aircraft Transportation System (SATS)
  - SATS High Volume Operation (HVO) Concepts
- Small Aircraft Pilot Assistant (SAPA)
- System Evaluation with Human in the Loop Simulation
- Example Scenario
- Summary and Future Work
Underutilized Airports and Airspace ... 
... an Opportunity for Increasing Mobility

Expanding Accessibility to several times more destinations

Airports today with “near all weather” availability

Of 5,400 public-use airports, only 715 (13%) have precision instrument approaches (ILS)

Near all-weather accessibility to 5,400 public-use airports?

- 22% within 30 minutes of major/hub airport
- 41% within 30 minutes of any commercial airport
- 93% of population within 30 minutes of SATS-type airport

NASA/NCAM Small Aircraft Transportation System (SATS) Project

Five Year Goal

➢ Demonstrate key airborne technologies for precise guided accessibility in small aircraft in near-all weather conditions to virtually any small airport in non-radar, non-towered airspace

➢ Focused on enabling four operating capabilities
  - Higher Volume Operation at Non-Towered/Non-Radar Airports
  - Lower Landing Minimums at Minimally Equipped Landing Facilities
  - Increase Single-pilot Crew Safety & Mission Reliability
  - En Route Procedures & Systems for Integrated Fleet Operations

Higher Volume Operations Objective

Enable simultaneous operations by multiple aircraft in non-radar airspace at and around small non-towered airports in near all-weather conditions

High Volume Operation (HVO)

- Proposed by NASA/NCAM SATS Project
- A self-controlled airspace (SCA) established around the airport
- Pilots responsible for self-separation in SCA, via ADS-B and onboard traffic conflict management system.
- Airport Management Module (AMM) responsible for Approach Sequencing and Airport Info.
- ATC only providing separation service outside SCA
Self Controlled Space (SCA)

- Similar to GPS T approach
  - 2 IAFs, IF, FAF, 2 DFs
- Around 20 nm in diameter, 3000 AGL in height

Plan View

Profile View
Example Operation – Vertical Entry

- Aircraft is on traditional IFR flight plan
- ATC clearance to the IAF at the altitude above SCA

- AMM periodically broadcasts airport information
  - # of aircraft currently in the SCA
  - # of aircraft requesting landing
  - ATIS information

- Pilot monitors AMM broadcast message for situation awareness

- When aircraft is close to the airport, pilot requests landing sequence from the AMM
- Pilot receives a “STNDBY” response from AMM
Vertical Entry (cont.)

- Aircraft flies to and holds at IAF until arrival sequence is available

- When a vertical entry is permitted pilot receives from AMM entry notification: “N700AE, VEN, IAF ANNIE, Following N385CP, MAHF ANNIE”

- Using on-board displays, pilot verifies altitude below (within SCA) is clear

- Pilot requests clearance from ATC to descend and descends to lowest available altitude and holds as needed
Vertical Entry (cont.)

- Pilot starts approach when spacing criteria with the leading aircraft is met
- During the approach, pilot maintains self-spacing and self-separation
Small Aircraft Pilot Assistant

- The HVO concept imposes high pilot workload in the terminal area.
- Realizing HVO concepts requires advanced automated cockpit system
  - Increasing situation awareness
  - Decreasing pilot workload
  - Aiding pilot decision-making
- Small Aircraft Pilot Assistant (SAPA), design based on NASA documents, address minimum SATS demo requirements
  - Adams, Catherine, Maria Consiglio, Kenneth Jones, et.al., 2004, Development of the SATS HVO Operational Concept, NASA Langley Research Center.
Head Down Moving Map Display
Human-in-the-loop HVO Simulation

Rockwell Commander C700

Moving Map
NAV Display

SAPA

Autonomous Intelligent Pseudo A/C

AirSim

AMM

Ground Controller Console
Distributed Simulation System

Simulation and External Display
SGI Onyx Reality II/IRIX 6.2

Moving Map Display
PC/WIN 2000

Pilot Interface
PC/WIN NT

Pseudo AC/ATC Agents
PC/LINUX

AMM Module
PC/LINUX

AirSim Server
PC/LINUX

TCP/IP

UDP/IP

Digital/Analog Input

Video Signal

Video Signal

Video Signal

Video Signal
Head Up Display in Flight
Out-of-Window Traffic View
SCA at KCNW, WACO, TX

### KCNW/CNW SATS Rwy 17L

<table>
<thead>
<tr>
<th>AWOS</th>
<th>134.42</th>
<th>133.3</th>
<th>124.0</th>
<th>121.7</th>
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<tbody>
<tr>
<td>SATS</td>
<td>134.42</td>
<td>133.3</td>
<td>124.0</td>
<td>121.7</td>
</tr>
<tr>
<td>Final Apch Crs</td>
<td>171°</td>
<td>2000'</td>
<td>860'(391')</td>
<td>470'</td>
</tr>
<tr>
<td>Minimum Alt</td>
<td>171°</td>
<td>2000'</td>
<td>860'(391')</td>
<td>470'</td>
</tr>
<tr>
<td>MDA(H)</td>
<td>860'(391')</td>
<td>470'</td>
<td>TDZE 469'</td>
<td></td>
</tr>
<tr>
<td>APT Elev</td>
<td>470'</td>
<td>TDZE 469'</td>
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<tr>
<td>Ground</td>
<td>3600'</td>
<td></td>
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**Missed Apch:** Climb to open alt., direct LOUIE or RAZVY and hold.

**Alt Set:** INCHES

**Extension Angle:** 1.5

**Ground speed:** 70 90 100 120 140 160

**MAP at TITAH**

<table>
<thead>
<tr>
<th>STRAIGHT-IN LANDING RWY 17L</th>
<th>CIRCLE-TO-LAND</th>
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<tbody>
<tr>
<td>NDB(H) 860'(391')</td>
<td>940'(470')-1</td>
</tr>
<tr>
<td>MAX</td>
<td>980'(510')-1'2</td>
</tr>
<tr>
<td>1020'(550')+2</td>
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</table>

**VNAV DA(H) in lieu of MDA(H).**
# Example Scenario

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<tbody>
<tr>
<td>Aircraft Type</td>
<td>Cessna 172</td>
<td>Commander 700 (Piloted)</td>
</tr>
<tr>
<td>Flight ID</td>
<td>N865CP (Leading)</td>
<td>N700AE</td>
</tr>
<tr>
<td>Locations</td>
<td>Near RAZVY</td>
<td>Near LOUIE</td>
</tr>
<tr>
<td>Altitude (ft)</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Planned IAF</td>
<td>RAZVY</td>
<td>LOUIE</td>
</tr>
<tr>
<td>Cruise Airspeed (knots)</td>
<td>125</td>
<td>135</td>
</tr>
<tr>
<td>Hold Airspeed (knots)</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Initial Approach Airspeed (knots)</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>Final Approach Airspeed (knots)</td>
<td>80</td>
<td>90</td>
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- Non-Nominal scenario: Leading aircraft has sudden loss of the power
- Loss of separation occurs shortly after piloted aircraft starts approach
Summary

- An onboard pilot decision aid system, called the Small Aircraft Pilot Assistant, is designed dedicated to SATS aircraft conducting HVO.

- The desired characteristics of the SAPA are attributed to Artificial Intelligence techniques used, such as Fuzzy Logic and Expert Systems.

- A real-time, multi-aircraft, pilot-in-the-loop simulation system is developed for the pilot evaluation of the SAPA.

- Preliminary pilot test results show that the SAPA is a promising system to satisfy the cockpit system requirements of the SATS HVO.
Future Work

- New Microsoft Flight Simulation Based, Multi-Human in the loop simulation system
- New pilot information display

OUTSIDE SCA

<table>
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<tr>
<th>SCA:</th>
<th>SURV:</th>
<th>IAF:</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATUS: NP</td>
<td>APDL:</td>
<td>MAHF:</td>
</tr>
</tbody>
</table>

>>> LATERAL ENTRY, FOLLOW N865CP, MAHF LOUIE

To: (1) LOUIE 115.3
2.4 NM ETE: 00:01:12
NEXT: (2) FOSTR
260° 7.4NM

Scale: 10 NM