The CASSIS Flight Trials

Joel K. Klooster GE Aviation
Overview

• CASSIS Background
• Trajectory Based Operations
  • How do we get from here to there?
• CASSIS Flight Trials
  • Objectives
  • Setup
  • Results
• Conclusions & Next Steps
CASSIS - CTA / ATM
System Integration Studies

- Explore the concept feasibility
- Conduct several hundred trials with revenue-flights
- Produce CTA ConOps document

What are we trying to solve?

**A two-pronged approach**

**POLICY:**
Integration of Air+Ground and C+N+S
Industry Consensus: RTCA NextGen Task Force

**TECHNICAL:**
Use best existing equipage for Mid-Term
Importance of operational evaluations that
“Learn and Leave Behind”
Take managed investment risks in deployment

**“Path to Performance”**

RNAV = (2D) Flexible Routing

RNP = (3D) RNAV +Integrity +Availability +Containment

Value of CASSIS

Bringing all players together to “break the cycle”

Airframers & Avionics Suppliers

Only build new functionality
IF
the Operators will buy it!

ATC

Only provide benefits
IF
Supplier equipage available, and supports ATC goals

Airline Operators

Only buy new functionality
IF
ATC offers benefits for it!

imagination at work
Stockholm – Arlanda (ESSA)
Objectives of Trial Flights

Delay En Route

- Avoid holdings by taking delay en route instead

Improve Arrival Management

- Strategic Planning – extend planning horizon

Delay on Ground

- Pop-up flights disrupt the arrival sequence

“Royal Flights”

- 12 flights, RTA to IAF or Runway
CASSIS 2008 CTA Flight Trials
- Over 300 flight tests!

<table>
<thead>
<tr>
<th></th>
<th>Round 1 June-July 2008</th>
<th>Round 2 September, 2008</th>
<th>Round 3 December 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flights</td>
<td>~100</td>
<td>~100</td>
<td>~100</td>
</tr>
<tr>
<td>Traffic situation</td>
<td>Low</td>
<td>Low and High</td>
<td>Low and High</td>
</tr>
<tr>
<td>Delay on ground</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>“Royal Flights”</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CTA as a spacing tool</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Entry points</td>
<td>Hammar (Northern)</td>
<td>Hammar (Northern)</td>
<td>Hammar (Northern) Eltok (Western)</td>
</tr>
<tr>
<td>Aircraft Types</td>
<td>MD80 Family, B737NG</td>
<td>MD80 Family, B737NG</td>
<td>MD80 Family, B737NG A330-300</td>
</tr>
</tbody>
</table>
Completed Cassis Flights
All types of aircraft and trial types

Percent of flights

Error (sec)

- B737 (157 flights)
- MD80 (102 flights)
- A330-300 (6 flights)
Intent Bus in B737 since 2006
- ARINC 702A-1 Trajectory Bus
  - Aircraft current-state information 2Hz
  - Aircraft 4D trajectory predictions (Intent)
    - Each minute or when FP changes
    - Full trajectory to runway
    - Includes vertical wpts and turns

ARINC 429 Trajectory Bus
ACARS

Dedicated ARINC 429 Bus and/or via ACARS

Current A/C State and Trajectory Predictions

AOC

ATC

imagination at work

GE – Aviation
7/31/2009
ACARS Downlink: Stockholm to Malmo Flight

Route: ESSAESMS10

---starts here---

1,,,N59397E017581.
C,,,N59376E018019,500,090227.
0,R,557,N59359E017585,769,090306.
0,L,934,N59302E017443,1279,090456.
0,,,N59070E017184,2511,090907.
0,R,1893,N59044E017155,2604,090932.
B,,,N58515E016548,3032,091149.
8,,,N58380E016335,3500,091408.
0,,,N58366E016312,3500,091423.
0,,,N57592E015342,3500,092051.
0,,,N57388E015041,3500,092420.
0,,,N57024E014122,3500,093032.
0,,,N56455E013489,3500,093323.
9,,,N56354E013354,3500,093504.

---END---

Point Type: Fly-by waypoint
Turn Direction: Left

Turn Radius: 9.34 NM
Lat / Lon: N59°30.2', E017°44.3'
Altitude: 12,790 feet
Time: 09:04:56
Required Time of Arrival (RTA)

RTA accuracy based on the FMS precision ‘4D’ trajectory
6.0 second tolerance
Re programmable in Clb, Crz, Des

- Time
- Flight Path
- Distance
- RTA Waypoint
- Crew Entered RTA Time
- Time Window
- Maximum Speed Profile
- Minimum Speed Profile
- RTA Speed Profile

Crew Entered
RTA Time

RTA Speed Profile

RTA Waypoint

Flight Path
Distance

- ACT RTA PROGRESS 2/3
- RTA WPT EPH
- RTA SPD 273/.733
- RTA 1012:00 z
- TIME ERROR ON TIME GMT 0930:30Z
- DIST - TO EPH 405 NM ALT ETA 1012:05
- FIRST - RTA WINDOW - LAST
1008:23 z 1014:30Z
< LIMITS
AVTECH NowCast wind uplink
### Results of Royal Flights

<table>
<thead>
<tr>
<th></th>
<th>CTA Accuracies</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>IAF</td>
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<tr>
<td><strong>Rel. Mean</strong></td>
<td>-0.4 sec</td>
</tr>
<tr>
<td><strong>Rel. σ</strong></td>
<td>5.9 sec</td>
</tr>
<tr>
<td><strong>Abs. Mean</strong></td>
<td>4.0 sec</td>
</tr>
<tr>
<td><strong>Abs. σ</strong></td>
<td>3.9 sec</td>
</tr>
</tbody>
</table>
Impact of speed and altitude constraints
Separation Evaluation

• Using Quick Access Recorder (QAR) Data
• “Time Shift” one flight for $\Delta$RTA relative to a second flight
• Examine flights with RTA at runway only
  • Flights to same runway and STAR only
• 33 valid flight pairs $\Rightarrow$ 66 comparisons
• Runway spacing of 60 – 120 seconds
# Theoretical Separation Evaluation

<table>
<thead>
<tr>
<th>Target Landing Separation</th>
<th>3NM / 1000 ft Separation Violations</th>
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<tbody>
<tr>
<td></td>
<td>Number</td>
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<tr>
<td>60 sec</td>
<td>64</td>
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<tr>
<td>75 sec</td>
<td>57</td>
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<tr>
<td>90 sec</td>
<td>9</td>
</tr>
<tr>
<td>105 sec</td>
<td>1</td>
</tr>
<tr>
<td>120 sec</td>
<td>0</td>
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</tbody>
</table>
Evaluation of Individual Cases Revealing

Flights occurred on different days, with very different wind conditions
Scandinavian Airlines reports:

>4000 Green Approaches so far

- 60kg fuel saved on each
- 756 Metric Ton CO2 reduced
- 2,300 kg of NOx reduced
- 240,000 kg of fuel saved

SAS-Sweden potential 36,000 Green Approaches yearly into Stockholm alone

- $5.8M fuel reduction plus $4M yield improvement yearly
- 23,000 Metric Ton CO2 reduction yearly
- 79 Metric Ton of NOx reduction yearly
- Noise reduced by 50% (65db exposure area)

LFV committed to 80% “Green Approaches” by 2012!
Conclusions

• 4 second accuracy at IAF, < 15 seconds at the runway threshold

• Wind error major impact on time accuracy

• Flap extension and speed/altitude constraints significant role beyond IAF

• Separation must be dealt with, but not an impossible problem to solve

• Further integration with ATM tools an integral next step
Next Steps
CASSIS 2

Continue success of CASSIS

Expand to other operators and aircraft

- Novair, KLM
- B737, A320

Improve integration with ground equipment

- Thales ATM
- Egis Avia
MINT – Minimum CO$_2$ in the TMA

AIRE project
Sponsored by SESAR
RNP AR flights with Novair A321
Further use of CTA in descent
4DTRAD Standardization
RTCA SC-214 / EUROCAE WG 78

- 4D Trajectory Datalink (4DTRAD)
- Queue Management using RTA / CTA

- Primarily focused on communication, but navigation and surveillance also important:
  - How will trajectory be used?
  - How will RTA / CTA be used?
  - What implications does this have for the FMS?
  - What impact do different implementations have?
The need for standardization

- Downlink of performance?
- Number of Speed Changes?
- Monitoring (who and when)?

Two Approaches

- New EUROCAE WG focusing on 4D Nav
- RTCA Committee looking at TBO at a higher level
Thank You!

Joel K. Klooster
GE Aviation
3290 Patterson Ave SE
Grand Rapids, MI 49512-1991

joel.klooster@ge.com
+1 616.241.7501