CONTRACT-BASED AIR TRANSPORTATION SYSTEM (CATS)
Operational Assessment

A Human in the Loop experiment to assess the CoO concept from ATCO point of view

Presented by Sandrine Guibert, Giorgio Matrella and Jean-Yves Grau
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Goal

- **Proof of Concept Study, following E-OCVM**

![E-OCVM Concept Lifecycle Model](image)

- The CATS operational assessment is focused on the En-route part and covers the V1 level (Scope) and V2 level (Feasibility) of the Level of Maturity.
Goal

- First operational assessment

- Evaluate the operational acceptability of the Contract of Objectives and associated Target Windows concepts from the controllers' point of view.
  - Operational acceptability will be evaluated in the context of the transfer of responsibility area between two ANSPs.
  - Evaluation environment is restricted to 2 en-route sectors (at the border of the two ANSPs) which manage the traffic.
HIL1 Hypothesis

- CoO implementation allows safe operations.
- CoO is still manageable even with increase of traffic as foreseen in 2020.
- CoO implementation affects positively the flight within the sector (flight duration ...).
- Implementation of TWs ensures the respect of schedule.
- TWs integrate flexibility to cope with uncertainty.
- The working methods offered to ATCOs, as a result of the CoO implementation, are feasible and acceptable (task sharing, role and responsibility, as well as the offered support tools).
- Implementation of CoO results is still acceptable workload to ATCOs.
Methodology

■ Evaluation principles:
  • SESAR KPAs (Key Performance Area): system performance
    ‣ 4 KPAs are applicable for CATS
      ▪ Safety
      ▪ Capacity
      ▪ Efficiency
      ▪ Predictability

  • Objectives relating to human performance
## Operational issues evaluation

<table>
<thead>
<tr>
<th>Objectives relating to system performance</th>
<th>Objectives relating to human performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAFETY</td>
<td>Feasibility and acceptability of the ATCos' working methods due to the CoO execution</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>Impact of CoO execution on ATCOs' performance</td>
</tr>
<tr>
<td>EFFICIENCY</td>
<td>Impact of CoO on ATCOs' activity</td>
</tr>
<tr>
<td>PREDICTABILITY</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAF.LOCAL.ER. PI (1, 2, 3, 5, 6 &amp; 8)</td>
<td>Workload: ISA, NASA-TLX, Interviews, Observations, Performance outcomes, Questionnaire</td>
</tr>
<tr>
<td>CAP.LOCAL.ER. PI (2, 8, 10, 11, 12 &amp; 13)</td>
<td>Situation Awareness: SASHA_Q, Interviews, Observations, Performance outcomes, questionnaire</td>
</tr>
<tr>
<td>EFF.LOCAL.ER. PI (1, 7, 8, 9, 10, 11)</td>
<td>Error production and management: Observations, Questionnaire, Interviews, Performance outcomes</td>
</tr>
<tr>
<td>PRED.LOCAL.ER. PI (1 &amp; 2)</td>
<td>Operator's activity: Cognitive processes, Decision making, Risk management, Constraints, etc.</td>
</tr>
<tr>
<td>Number of TWs fulfilled</td>
<td>Collaborative activity: Communications (number, time, content, speaker and receiver, etc.)</td>
</tr>
</tbody>
</table>
Experimental environment

- **Traffic:**
  - Real traffic
  - Traffic load has been adapted to the airspace
    - Current level of traffic (2008)
    - 2020 traffic load (EUROCONTROL STATFOR)

- **Simulation facilities**
  - SkySoft platform (rapid prototyping adapted from SkyGuide simulator)
  - 2 sectors (MI1 & KL1)
  - EXE and PLN on each CWP
  - No pseudo-pilot:
    - Automatic order execution by aircraft
    - Automatic hand over/ assume by feed sectors
Experimental environment

<table>
<thead>
<tr>
<th>ACC</th>
<th>Sector</th>
<th>Min FL</th>
<th>Max FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIR</td>
<td>LIRMI1</td>
<td>FL275</td>
<td>FL345</td>
</tr>
<tr>
<td>LSA</td>
<td>LSAKL1</td>
<td>FL275</td>
<td>FL345</td>
</tr>
</tbody>
</table>

KL1 FL275 – FL345 MI1 FL275 – FL345

Exe Pln Exe Pln

KL MI
One CWP
HMI

- Adjacent TW

Geographical position

Effective Time

Time min/max

Preferred FL

FL min/max
HMI

- Superimposed TW

Time min/max to cross TW

TW geographical position
Conduct of the experiment

- Duration: 10 days
- Dates:
- Location: Skysoft premises – Geneva
- Four controllers from ENAV S.p.A
- One on site pre-training session the 2\textsuperscript{nd} October 2008 at Roma ACC
## Conduct of the experiment

### Timetable:

<table>
<thead>
<tr>
<th>Day</th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>20th. October</td>
<td>Simulation devices presentation</td>
<td>Familiarization</td>
</tr>
<tr>
<td>21th. October</td>
<td>Familiarization</td>
<td>Operational training (session 1)</td>
</tr>
<tr>
<td>22th. October</td>
<td>Operational training (session 2)</td>
<td>Operational training (session 3)</td>
</tr>
<tr>
<td>22th. October</td>
<td></td>
<td>Experimental runs #1, 2 &amp; 3</td>
</tr>
<tr>
<td>24th. October</td>
<td>Experimental runs #4, 5 &amp; 6</td>
<td></td>
</tr>
<tr>
<td>27th. October</td>
<td>Familiarization and Training</td>
<td>Experimental runs #7 &amp; 8</td>
</tr>
<tr>
<td>28th. October</td>
<td>Experimental runs #9, 10 &amp; 11</td>
<td></td>
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<tr>
<td>29th. October</td>
<td>Experimental runs #12, 13 &amp; 14</td>
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<tr>
<td>30th. October</td>
<td>Experimental runs #15 &amp; 16 – Final Debriefing</td>
<td></td>
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<tr>
<td>31th. October</td>
<td>Spare day</td>
<td></td>
</tr>
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</table>
## Conduct of the experiment

### Daily Programme

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0845</td>
<td>Set-up in Operations Room</td>
</tr>
<tr>
<td>0900 – 1045</td>
<td>Exercise 1 + Debriefing &amp; Questionnaires</td>
</tr>
<tr>
<td>1045 – 1100</td>
<td>Break</td>
</tr>
<tr>
<td>1100 – 1245</td>
<td>Exercise 2 + Debriefing &amp; Questionnaires</td>
</tr>
<tr>
<td>1245 – 1415</td>
<td>Lunch</td>
</tr>
<tr>
<td>1415 – 1600</td>
<td>Exercise 3 + Debriefing &amp; Questionnaires</td>
</tr>
</tbody>
</table>
Experimental plan

- Independent variables:
  - With TW and without TW
  - Traffic load (current 2008 and 2020)
- 4 similar traffic scenarios
Experimental Plan

- **Dependent variables:**
  - **Observations**
    - ATCOs performance (Overt The Shoulder – OTS rating scales, FAA)
    - Spontaneous verbalisations
  - **Performance measurements**
    - STCA
    - ATCO orders
    - Flight duration
    - Fulfilled TW
  - **Self assessment**
    - Workload : ISA & NASA-TLX
    - Situation awareness : SASHA_Q
    - Safety feeling : questionnaire on risks & hazards
  - **Post run interviews & Post experimental questionnaires (concept, performance, cooperation, simulation)**
### Experimental plan

**OTS Rating scales**

<table>
<thead>
<tr>
<th>Run: Observer: Sector:</th>
<th>MI1</th>
<th>KL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXE: IM VT RL LX PLN: IM VT RL LX</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>OTS – HIL1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>Below</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fully</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exceptional</td>
<td></td>
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</tr>
</tbody>
</table>

- Maintaining separations
- Maintaining efficient air traffic flow
- Maintaining attention & SA
- Coordinating
- Communicating – Cooperation
- Performance multiple tasks
- Managing sector workload
- Overall performance
Experimental plan

- 16 runs and 32 measures: 2 traffic loads per run
  - 8 runs “with TW” for 2008 & 2020 traffic loads
  - 8 runs “without TW” for 2008 & 2020 traffic loads
  - The 4 experimental conditions were compared for each ATCOs team (EXE-PLN for MI1 & EXE-PLN for KL1)
Initial Results

- **Workload self assessment (NASA TLX)**

  - **NASA TLX KL EXE**
    - TW: $p > 0.400815$
    - Load: $p < 0.020863$

  - **NASA TLX Sector MI**
    - TW: $p = 0.674424$
    - Load: $p = 0.011719$

  - **NASA TLX Sector KL (PLN)**
    - TW: $p = 0.326990$
    - Load: $p = 0.025063$

  - **NASA TLX Sector MI (PLN)**
    - TW: $p = 0.207579$
    - Load: $p = 0.017291$

- Not significant between “with TW” and “without TW”
- Significant between 2008 and 2020 traffic load

Wilcoxon Tests
Initial Results

- **Workload (ISA)**

  - **ISA KL EXE**
    - TW: $p > 0.88638$
    - Load: $p < 0.046400$
  
  - **ISA MI EXE**
    - TW: $p = 0.123486$
    - Load: $p < 0.029975$
  
  - **ISA KL PLN**
    - TW: $p > 0.207579$
    - Load: $p < 0.035693$
  
  - **ISA MI PLN**
    - TW: $p = 0.575403$
    - Load: $p < 0.035693$

- Not significant between “with TW” and “without TW”
- Significant between 2008 and 2020 traffic load
Initial Results

- Situation Awareness (SASHA-Q)

- Not significant between “with TW” and “without TW”.
- Significant between 2008 and 2020 traffic load
Initial Results

- **OTS Performance**

<table>
<thead>
<tr>
<th>TW: p &gt; 0, 398025</th>
<th>TW: p &gt; 0, 674987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not significant between “with TW” and “without TW”</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>OTS Performance KL</th>
<th>OTS Performance MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>Median</td>
</tr>
<tr>
<td>25%-75%</td>
<td>25%-75%</td>
</tr>
<tr>
<td>Min-Max</td>
<td>Min-Max</td>
</tr>
<tr>
<td>2020 2020TW</td>
<td>2020 2020TW</td>
</tr>
<tr>
<td>1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5</td>
<td>1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5</td>
</tr>
</tbody>
</table>
Initial Results

- Flight duration

<table>
<thead>
<tr>
<th></th>
<th>REF</th>
<th>WITHOUT</th>
<th>WITH TW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>12.8</td>
<td>13.0</td>
<td>13.2</td>
</tr>
<tr>
<td>25%-75%</td>
<td>13.4</td>
<td>13.6</td>
<td>13.8</td>
</tr>
<tr>
<td>Min-Max</td>
<td>13.6</td>
<td>14.0</td>
<td>14.2</td>
</tr>
<tr>
<td>FLIGHT DURATION MI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>15.0</td>
<td>15.5</td>
<td>16.0</td>
</tr>
<tr>
<td>25%-75%</td>
<td>16.0</td>
<td>16.5</td>
<td>17.0</td>
</tr>
<tr>
<td>Min-Max</td>
<td>17.0</td>
<td>18.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

• Not significant between “with TW” and “without TW”
• Significant between reference and other conditions
Initial Results

- STCA (Calibration: 5Nm, 900Ft, 1mn20s)

Wilcoxon Tests

- Not significant between “with TW” and “without TW”
- But interpretation of these data should be taken carefully: only one real STCA observed during the 16 runs.
Initial Results

- ATCOs Orders

Total number of ATCOs orders is not significant (from p>0.068704 to p>0.888636)
Post run interviews

- Concept has been described as:
  - Feasible & Acceptable
  - TW was manageable, for 2008 as well as 2020
  - Traffic volume constrained ATCOs more than the TW
  - No impact on safety achievement
  - Enough space for manoeuvres to deal with conflicts, except when there were two superimposed Target Windows (2SUP TW)

- Potential improvements
  - Coordination tools are needed, mainly when traffic increases
  - TW calculation should take into account the airspace (avoid SUP TW on main crossing points, add more space between 2 SUP TW...)

Post experimental questionnaire

- TW ATCOs opinions:
  - Easy to use for EXE & PLN
  - Modifies the way the conflicts are detected and solved for the EXE but not for the PLN
  - Improves the traffic predictability but does not impact safety, capacity & efficiency
  - Subjective workload slightly impacted at high traffic load but not the Situation Awareness (SA)
  - Communication & cooperation between EXE & PLN are not altered by the TW use
  - TW is acceptable although more specific CWP tools should be developed when traffic load increase
  - The HIL1 experiment and the simulation facilities enable good understanding of the CoO concept and its potentialities.
Conclusions

- CoO concept is manageable with the 2008 & 2020 traffic loads, without any impact on Safety.
- ATCO perceived more workload in 2020, even if this was not measured by the quantitative workload data:
  - increase of traffic in 2020 features but still with the current routes structure and current tools.
  - need to shift ATCOs approach from a sector to a system integrated view.
- Level of SA remains the same
- Simulation facilities allow assessment of HIL1 goals:
  - Development of coordination tools between ATCOs
Thank you for your attention!