Background
CAPAN

Simulation Methodology

Sector Capacity

Controller Workload
Fast Time Simulation

Technique

Discrete Event
Fast Time Simulation in ATM

- Events at Sector
- Actions
- Tasks
- Workload
CAPAN

RCAPAN 70%

Regression Analysis
RAMS

- CAPAN dedicated version of RAMS (Reorganised ATC Mathematical Simulator owned by ISA Software)
- Fast-time simulator as others available on the market
- It allows flexible and detailed modeling of both ACC and TMA environment
70% Workload Threshold

- Theoretical Sector Capacity is attained when controller workload reaches 70% of the absolute working time, i.e. 42 minutes in an hour.
- 30% represents tasks which cannot be captured by discrete events, e.g. a general monitoring of the radar screen or recuperation time.
- 70% threshold has been assessed through a process of fine-tuning of the discrete event logic when the first CAPAN studies were carried out together with several Real-Time simulations.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Interpretation</th>
<th>Recorded Working Time during 1 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 % or above</td>
<td>Overload</td>
<td>42 minutes +</td>
</tr>
<tr>
<td>54 % - 69 %</td>
<td>Heavy Load</td>
<td>32 - 41 minutes</td>
</tr>
<tr>
<td>42 % - 53 %</td>
<td>Medium Load</td>
<td>25 - 31 minutes</td>
</tr>
<tr>
<td>18 % - 41%</td>
<td>Light Load</td>
<td>11 - 24 minutes</td>
</tr>
<tr>
<td>0 % - 17 %</td>
<td>Very Light Load</td>
<td>0 - 10 minutes</td>
</tr>
</tbody>
</table>
Regression Analysis

- Mathematical technique for data analysis
- Type of regression specifically chosen for CAPAN purposes and based on dependency between workload and sector traffic entry rates
- Used to average sector behaviour over the simulation period, generally 24 hours
- Used to perform workload and traffic analyses based on specific periods of the day, traffic flows, etc
Controllers

- Fundamental importance for the validation of the simulation scenarios
- Provide support to define actual flight routings, procedures, tasks, conflict detection and resolution logic and other simulation parameters
- Generally working in a team throughout the study together with two CAPAN simulation experts
- At least two active controllers from every simulated unit
CAPAN Input Data
Input Data

**Environment Data**
- Route network
- Airspace structure
- Sectors...

**Basic traffic Data**
- Flight plans (24H Traffic)
- A/C Performances...

**Simulation Parameters**
- Conflict Detection/Resolution
- Procedures ...
- Separation minima's

**ATC Tasks**
- Sector manning

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RCAPAN Simulation Engine
Environment Data

- Directly available in Network Manager Database
- Based on AIRAC Cycle Publication
- Complemented with AIP and tactical information
- Totally customisable
Basic Traffic Data

Flight plans (24H Traffic)

- Three different kinds of traffic data available in Eurocontrol Network Manager common archive DDR2:
  1. Initial demand: last update of flight plans
  2. Regulated Demand: flight plans affected by flow restrictions
  3. Actual Demand: flight profiles based on coordinated position reports
- One or more samples are chosen to be representative of the typical flows in the area of interest
- Once ready traffic is iterated n times to reproduce random situations (e.g. entry times, performances)
Basic Traffic Data
Flight plans (24H Traffic)

Initial demand based on last update of the flight plan is used to:
- Preserve the original intentions of the flights as far as possible
- Avoid smoothing of the traffic due to the effect of regulations
- Keep original peaks of traffic
- Keep traffic complexity without the effect of controller actions

Actual demand is however used to complement flight plan information
Basic Traffic Data

Aircraft Performance

- **BADA**: Base of Aircraft Data
  Eurocontrol Database with nominal performances
- Fundamental for trajectory calculation
- Totally customisable to local procedures and company policies
Simulation Parameters

- Several parameters required for fast-time simulation
- CAPAN tailored parameters for ACC and TMA environment
- Logic for conflict detection/resolution mechanisms associated to separation minima
- Parameters to allow proper reproduction of the Procedures
Controller Tasks and Sector Manning

- Standard model for controller tasks for both ACC and TMA environment
- Totally Customisable depending on system capabilities, specific procedures, separation minima, etc
- Divided into 5 main task categories:
  1. Flight Data Management
  2. Conflict Search
  3. Coordination
  4. Standard Radio Telephony
  5. Radar
- Applicable to single-double man operations, multi-sector planner, etc.
CAPAN: the logic in practice
Events and Tasks
# Example of ATC Tasks recorded

## GAPLI sector

<table>
<thead>
<tr>
<th>TIME</th>
<th>TASK</th>
<th>Definition</th>
<th>WORKLOADS (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02:47</td>
<td>1</td>
<td>Acknowledge of a new flight</td>
<td>PC 1</td>
</tr>
<tr>
<td>03:03</td>
<td>44</td>
<td>Receipt of a flight progress strip</td>
<td>PC 7</td>
</tr>
<tr>
<td>03:04</td>
<td>51</td>
<td>Routine conflict search to establish sector planning clearance</td>
<td>EC 5, PC 8</td>
</tr>
<tr>
<td>03:17</td>
<td>66</td>
<td>First call from an a/c entering the airspace of a new ACC</td>
<td>EC 10, PC 8</td>
</tr>
<tr>
<td>03:17</td>
<td>64</td>
<td>Additional R/T for a traffic entering from oceanic airspace</td>
<td>EC 18</td>
</tr>
<tr>
<td>03:44</td>
<td>72</td>
<td>Last R/T message to an a/c leaving the sector</td>
<td>EC 10, PC 5</td>
</tr>
<tr>
<td>03:44</td>
<td>74</td>
<td>Propose radar transfer</td>
<td>EC 3</td>
</tr>
<tr>
<td>03:44</td>
<td>45</td>
<td>Removal of the flight progress strip</td>
<td>PC 2</td>
</tr>
</tbody>
</table>

## TAKAS sector

<table>
<thead>
<tr>
<th>TIME</th>
<th>TASK</th>
<th>Definition</th>
<th>WORKLOADS (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>03:12</td>
<td>44</td>
<td>Receipt of a flight progress strip</td>
<td>PC 7</td>
</tr>
<tr>
<td>03:33</td>
<td>51</td>
<td>Routine conflict search to establish sector planning clearance</td>
<td>EC 5, PC 8</td>
</tr>
<tr>
<td>03:41</td>
<td>18</td>
<td>ACT message monitoring in the last sector</td>
<td>PC 4</td>
</tr>
<tr>
<td>03:43</td>
<td>75</td>
<td>Assume radar transfer from the previous sector of the same ACC</td>
<td>EC 3</td>
</tr>
<tr>
<td>03:44</td>
<td>67</td>
<td>First call from an a/c entering another sector of the same ACC</td>
<td>EC 10, PC 4</td>
</tr>
<tr>
<td>03:50</td>
<td>71</td>
<td>R/T instruction to an a/c to comply with a new planning clearance</td>
<td>EC 16, PC 3</td>
</tr>
<tr>
<td>03:53</td>
<td>69</td>
<td>Report of an a/c on reaching a specified level</td>
<td>EC 6, PC 3</td>
</tr>
<tr>
<td>03:55</td>
<td>72</td>
<td>Last R/T message to an a/c leaving the sector</td>
<td>EC 10, PC 5</td>
</tr>
<tr>
<td>03:55</td>
<td>74</td>
<td>Propose radar transfer</td>
<td>EC 3</td>
</tr>
<tr>
<td>03:54</td>
<td>45</td>
<td>Removal of the flight progress strip</td>
<td>PC 2</td>
</tr>
</tbody>
</table>
24 Hours Sector Activity

Sector Generic - Configuration X
608 Flights - 25 Iterations

Hours
No. Flights or Percentage
Flights
EC (%)
PC (%)
Peak Occ.
Calculation of Regression Capacity

Sector Generic - Organisation X

555 Flights in the 24H Traffic Sample (20 Iterations)

\[ y = 0.0125x^2 + 0.766x \]

\[ R^2 = 0.9785 \]

Sector Capacity

50/H
CAPAN: the workflow
CAPAN Workflow

Data Collection
Airspace/Traffic

DP1
Data Verification with Controllers
Observation of ATC Operations

Insert ATC Procedures
Add Standard Controller Tasks
Simulation Parameters
Aircraft Performance
Run Model

DP2
Verify Flight Profiles with Controllers:
ATC Procedures
Simulation Parameters
Controller Tasks
Aircraft Performance

Data Input
Run Model

Final Presentation
and Report

DP3
Verify with Controllers:
Initial Results
Simulation Scenarios
Simulation Fine Tuning

DP4
Verify with Controllers:
Initial Results

Network Manager nominated by the European Commission
**CAPAN Workflow**

**Data Collection**
Airspace/Traffic

**Tools**
NEST (SAAM + NEVAC)

**Demand Data Repository DDR2**

- Fast
- Reliable
- Data available for any AIRAC cycle

**Manual input of traffic and airspace**

- Time-consuming
- Traffic possibly to be built on a day-by-day basis
- Longer time for verification with controllers
Average Schedule

- Variable depending on data source

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Kick Off</td>
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</tr>
<tr>
<td>Data Preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DP1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Data Correct</td>
<td></td>
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<tr>
<td>Trial Runs</td>
<td></td>
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<tr>
<td>DP2</td>
<td></td>
<td></td>
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<tr>
<td>Sim Runs &amp; Debug</td>
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<tr>
<td>Results Analysis</td>
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<tr>
<td>DP3</td>
<td></td>
<td></td>
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<tr>
<td>Final Corrections</td>
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<tr>
<td>Final Presentation</td>
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</tr>
<tr>
<td>Report Preparation</td>
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<td></td>
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</tr>
</tbody>
</table>

ACC: 1 month
TMA: 1-2 months

3 days
2 days
1 day
1-3 weeks

Schedule depends on complexity of study and specific requirements
Data Preparation Meeting 1 (DP1)

- Generally a 3 day meeting but variable duration depending on number of scenarios and units to be assessed

- Main objectives:
  1. Introduce the Capan Method to the Controller Team
  2. Observation of ATC Operations
     ➔ To familiarise with local environment and working practices
  3. Verify traffic sample routes
  4. Verify traffic transfer procedures
  5. Introduction to Simulation Parameters
  6. Introduction to Controller Tasks
Data Preparation Meeting 2 (DP2)

- Generally a 2 day meeting but variable duration depending on type of unit and number of scenarios to be assessed

- Main objectives:
  1. Verification of flight profiles
  2. Aircraft performance adaptation to local conditions
  3. Controller Tasks definition
  4. Simulation parameters definition
Data Preparation Meeting 3 (DP3)

- Generally a 1 day meeting but variable duration depending on type of unit and number of scenarios to be assessed

- Main objectives:
  1. Simulation Verification
  2. Initial Results Checking

Note: for TMAs an extra meeting (DP4) is required for

1. Verification of Simulation Scenarios
2. Simulation fine tuning
CAPAN: Available Results
Available Results

Traffic
Capacity
Flights
Sector
Workload
Results Examples – Traffic Flows

24 hrs traffic sample
- More than 100 A/C
- 50 to 100 A/C
- 20 to 50 A/C
- 10 to 20 A/C
- 1 to 10 A/C
Results Examples – Traffic distribution

Number of Flights per Sector
Configuration 7 Sectors - 15 Iterations

- Sector 1: 582
- Sector 2: 478
- Sector 3: 545
- Sector 4: 384
- Sector 5: 206
- Sector 6: 364
- Sector 7: 483
Results Examples – Working time by category

Working Time by Category
Configuration 7 Sectors - 15 Iterations

- **Sector 7**: 9% Flight Data Management, 24% Conflict Search, 6% Coordinations, 42% StandardRT, 18% Radar
- **Sector 6**: 8% Flight Data Management, 24% Conflict Search, 5% Coordinations, 40% StandardRT, 24% Radar
- **Sector 5**: 7% Flight Data Management, 21% Conflict Search, 5% Coordinations, 35% StandardRT, 33% Radar
- **Sector 4**: 9% Flight Data Management, 26% Conflict Search, 4% Coordinations, 47% StandardRT, 13% Radar
- **Sector 3**: 6% Flight Data Management, 20% Conflict Search, 4% Coordinations, 36% StandardRT, 33% Radar
- **Sector 2**: 7% Flight Data Management, 22% Conflict Search, 1% Coordinations, 37% StandardRT, 32% Radar
- **Sector 1**: 9% Flight Data Management, 27% Conflict Search, 4% Coordinations, 43% StandardRT, 17% Radar

Network Manager
nominated by
the European Commission
Results Examples – Peak Workload

Peak EC Workload
Configuration 7 Sectors - 15 Iterations

<table>
<thead>
<tr>
<th>Sector</th>
<th>Workload (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector 1</td>
<td>65.1</td>
</tr>
<tr>
<td>Sector 2</td>
<td>74.0</td>
</tr>
<tr>
<td>Sector 3</td>
<td>94.1</td>
</tr>
<tr>
<td>Sector 4</td>
<td>42.0</td>
</tr>
<tr>
<td>Sector 5</td>
<td>35.1</td>
</tr>
<tr>
<td>Sector 6</td>
<td>58.8</td>
</tr>
<tr>
<td>Sector 7</td>
<td>57.0</td>
</tr>
</tbody>
</table>
Results Examples – Sector Behaviour

24 hrs Sector Behaviour - Sector 1
582 Flights - 15 Iterations

Hours (UTC)

No. Flights or Percentage

Flights EC (%) PC (%) Peak Occ.

Network Manager
nomination by the European Commission
Results Examples – Sector Behaviour

24 hrs Sector Behaviour - Sector 3
545 Flights - 15 Iterations

<table>
<thead>
<tr>
<th>Hours (UTC)</th>
<th>No. Flights</th>
<th>Flights</th>
<th>EC (%)</th>
<th>PC (%)</th>
<th>Peak Occ.</th>
<th>Dep. Airport 1</th>
<th>Arr. Airport 1</th>
<th>Dep. Airport 2</th>
<th>Arr. Airport 2</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Flights</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td>23</td>
<td>24</td>
<td>Flights</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results Examples – Conflict Areas

24 hours Traffic
Cell size is 5nm x 5nm
- More than 40 conf.
- 20 to 40 conf.
- 10 to 20 conf.
- 5 to 10 conf.
- 2 to 5 conf.
- 1 to 2 conf.
## Results Examples – Capacity and Throughput

### Configuration 7 Sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Flights</th>
<th>Average Flight Time</th>
<th>Sector Capacity</th>
<th>Total Flights</th>
<th>Global Throughput</th>
<th>Average Sector Crossings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector 1</td>
<td>582</td>
<td>7.6</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sector 2</td>
<td>478</td>
<td>5.1</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sector 3</td>
<td>545</td>
<td>8.1</td>
<td>35</td>
<td></td>
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<tr>
<td>Sector 4</td>
<td>384</td>
<td>7.0</td>
<td>48</td>
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<tr>
<td>Sector 5</td>
<td>206</td>
<td>6.4</td>
<td>34</td>
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<tr>
<td>Sector 6</td>
<td>364</td>
<td>4.3</td>
<td>41</td>
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<tr>
<td>Sector 7</td>
<td>483</td>
<td>7.1</td>
<td>48</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1293</strong></td>
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<td><strong>126</strong></td>
<td><strong>2.4</strong></td>
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Where to Use CAPAN

- Capacity
- Resectorise
- Research
- ATC/ATM
- CBA
CAPAN STUDIES Up to 2015

- Green: At least 1 CAPAN Study performed
- Orange: CAPAN Study performed and new one requested or in progress
- Red: CAPAN Study requested or in progress
- Yellow: Expressed interest in a CAPAN Study