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ATFM MODELLING CAPABILITY

AMOC

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Abstract :

This document gives a detailed description of the AMOC simulator, developed at EUROCONTROL Experimental Centre. It is intented for ATFM specialists and software engineers familiar with simulation technology and with a general knowledge of the ATFM concept and the CFMU daily operations. However, certain areas are adressed to software engineers who will maintain or enhance the AMOC functionality.

ATFM MODELLING CAPABILITY

AMOC

BY

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SUMMARY

In July 1992, a potential role for the EUROCONTROL Experimental Centre to conduct and support research into current and future ATFM, Air Traffic Flow Management, systems was identified by the Directors of the EEC and CFMU, Central Flow Management Unit.

Two tools NASPAC (National Airspace System Performance Analysis Capability) and CASA (Computer Assisted Slot Allocation) were installed at the EEC and an ATFM simulator, AMOC, was developed.

The main objective of this document is to show what kind of studies can be carried out with AMOC, e.g. :

- Identify bottlenecks in a given airspace organisation.
- Evaluate the current CFMU operations.
- Define contingency plans (in case of TACT/CASA failure).
- Assess the benefits of new ATFM strategies (slot allocation, re-routing scheme,...)

This note is intended for ATFM specialists and software engineers familiar with simulation technology and with a general knowledge of the CASA algorithm and the CFMU operations. Enough detail is included to assist those wishing to understand the overall architecture and functionality of AMOC, and those learning the system in order to maintain, enhance or simply use AMOC to conduct studies.

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1.0 Introduction

In July 1992 a potential role for the EUROCONTROL Experimental Centre EEC to conduct and support research into current and future air traffic flow management ATFM systems was identified by the directors of CFMU, the Central Flow Management Unit and the EEC. The long term purpose of the research was to define and validate new flow management concepts. Two areas of short term study and research were identified:

- Evaluation and improvement of the Pretactical ATFM operations: This include the identification of over-regulated or under-regulated sectors and analysis to suggest new solutions to maintain traffic within the declared capacities without any excessive delays.
- Evaluation and improvement of the Tactical ATFM system: This include the analysis of current ATFM measures to assess their effectiveness and delay costs, an assessment of multiple restrictions on a single traffic flow to identify possible redundancies; or worse, inconsistent duplications of effort.

The longer-term research is broad in scope. Ground delays are an effective but costly means of maintaining traffic flows within limits, causing considerable disruptions to airlines' schedules. Research using the simulation capability might identify opportunities for improved efficiency in regulation, by applying more sophisticated operations research techniques than those currently applied. Other tactics, such as dynamic rerouting, in response to identified imbalances between demand and capacity, are also possible. Investigation of such possibilities may benefit the airlines companies and passengers.

A centre of expertise was formed at EUROCONTROL Experimental Centre to implement the above recommendations and to conduct studies on behalf of the Central Flow Management Unit CFMU.

1.1 Intended Audience

This manual is intended for the EEC ATFM specialists and software engineers familiar with simulation technology, having a general knowledge of the CASA algorithm and the CFMU daily operations. Enough detail is included to assist persons wishing to understand the overall architecture and functionality of the AMOC system, and serves as effective step in learning the system for those who will maintain, enhance or simply use AMOC to conduct studies.

1.2 The Design and Evolution of AMOC

There never was an AMOC User Requirement Document , AMOC Software Requirement Document or AMOC Software Design Document. AMOC evolved to answer the needs of the specific studies conducted at the Eurocontrol Experimental Centre to support the CFMU operations. This evolution is a continuous process in response to new problems or requests from ATFM specialists.

1.3 What You Need to Run AMOC

The AMOC system will run on any UNIX workstation that runs X11 server. You will need Modsim and Simgraphics running on your workstation or server. Simgraphics provides the graphical user interface, window system, and toolkit necessary to run AMOC and compile AMOC interfaces. The UNIX workstation provides the C compiler and linker necessary to compile and link AMOC modules and interfaces.

1.4 AMOC validation

A validation study of AMOC was conducted in the framework of the FAP (Future ATM Profile) project in support of the IPEAS Task Force (Indicators for the Performance of the European ATM System). The validation traffic sample included the entire ECAC zone, and was for Friday the 21st of June 1996 (22 161 flights). The regulation plan was simulated was that applied by the CFMU on that day.

The following table shows a global comparison between AMOC results and the CFMU delay Analysis for the 21st of June 1996 (ref.: weekly summary 1996, weeks 19 to 26).

	AMOC	**CFMU report (21/06/96)**
Number of flights regulated	7056	6739
Number of flights delayed	3824	4303
Total ATFM delay (minutes)	91131	94238
Mean delay per delayed flight	24	22
Mean delay per regulated flight	13	14

Both the analysis of the sectors throughput and the comparison of the delays show that the simulations with AMOC simulator can be considered close to the CFMU operations.

1.5 What does AMOC offer?

Scientific research and engineering development related to the ATFM, are relying increasingly on computational simulation to augment theoretical analysis, experimentation, and testing. Many of ATC and ATFM problems are far too complex to yield to mathematical analyses. Simulations play an even greater role in providing solutions to our most challenging problems. In this context, The AMOC simulator was developed to simulate a wide range of ATC and ATFM functions, which can be applied to carry out studies to:

- identify the bottlenecks in a defined airspace organisation
- carry out a deep analysis of the CFMU operations (strategic and pre-tactical phases) and evaluate proposed solutions
- evaluate new alternative ATFM strategies and evaluate new approaches to adopt in case of TACT/CASA System failure (Preparation of contingency plans)

- validate the application of optimisation techniques (operations research, constraint-based approach) to reduce system-wide delays and congestion

1.6 About This Manual

This manual describes AMOC and contains fifteen chapters, including this one. If you're new to AMOC and the ATFM simulations, you should finish reading this introduction and then go to chapter two. It shows you the AMOC structure and describes briefly its components.

Chapter Three: Gives simple steps to guide you in conducting an ATFM study with AMOC.

Chapter Four: Gives you valuable information in obtaining the CFMU data necessary to start a simulation.

Chapter Five: describes the AMOC main window from which you can run any AMOC component.

Chapter Six: Describes the CASA algorithm, the input and output files format, the CASA services call and how to run CASA from AMOC main window.

Chapter Seven: Gives a short overview about the centralised and decentralised strategies, the SelFlow input and output files and how to run SelFlow

Chapter Eight: Describes DeliverCtot and gives the format of its input files

Chapter Nine: Shows how to use PerfAnalysis module to analyse the key performance measures of an ATFM strategy.

Chapter Ten: Contains valuable information about FRED tool, and how to use its four panels windows to create and update regulations and their correspondents flows.

Chapter Eleven: Describes the ATAC module responsible for formatting the CFMU traffic data.

Chapter Twelve: Describes the Flight Increase Processor Software which generates additional flights demand for simulation studies.

Chapter Thirteen: Describes the physical structures of AMOC directories and their contents. It gives also a detailed description of the Objects that make AMOC Graphical User Interface GUI.

Chapter Fourteen: Shows how CARAT can be integrated into AMOC for its validation and testing.

Chapter Fifteen: Describes the kind of studies that could be conducted using AMOC.

A glossary and a definition of special terms are at the end of this document.

1.7 What You Should Know To Maintain AMOC

This part addresses to people who will maintain AMOC. It assumes that you are familiar with UNIX, HP-UX, X11 server, the C programming language. It's particularly important that you know the Object-Oriented language Modsim and Simgraphics.

For more information about these topics, you can consult:

- The *HP-UX Reference Manual* for information about UNIX and HP-UX.
- The *C Programming Language* by Kernighan and Ritchie (or other reputable C books) for rules of programming in C.
- *Modsim II User's Manual and Reference Manual.*
- *Simgraphics II User's Manual.*
- *XLib Reference Manual and XLib Programming Manual.* These manuals are useful to understand the warning program writing with Xlib library.
- *X Window System User's Guide.*
- *Object-Oriented Analysis And Design with Applications* by Grady Booch.

2.0 AMOC

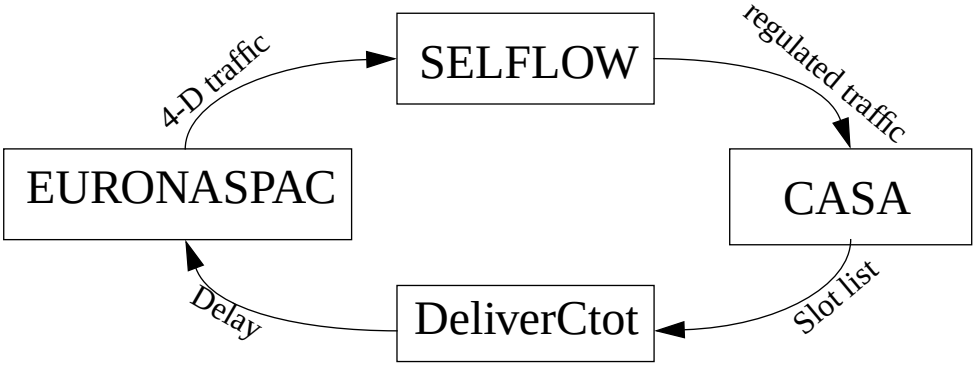
2.1 Overview

Traffic growth and changes in traffic patterns have caused increasing congestion and delay in European airspace. The Central Flow Management Unit (CFMU) continually seeks and develops methods to improve traffic flow management on an European scale to reduce delay and congestion. As part of this effort, the CFMU tasked the Eurocontrol Experimental Centre EEC with assessing new ATFM alternatives to generate better flow management strategies than those used currently. The EEC tackled the development of an ATFM simulator to experiment with new ways to resolve the problem of the European airspace congestion. The EEC ATFM simulator was born, and, through successive attempts to make it better, a final version of this simulator was shaped in the form of AMOC.

The **A**TFM **MO**delling **C**apability **AMOC**was designed to provide a test-bed for a wide spectrum of studies. It helps the executive planners and managers to address issues related to the airspace overload, the evaluation of a new ATFM strategy and the improvement of current or future operations.

AMOC is a collection of software that converts information concerning the structure of, and demand for, an airspace into measurements of performance of the system. AMOC is primarily based on the existing CFMU Computer Aided Slot Allocation CASA. CASA was incorporated as a fundamental component.

2.2 The topology of the old AMOC



By topology, we mean the basic physical building components of the system and how those parts are interconnected to provide the overall behaviour of AMOC.

AMOC was based on the existing CFMU programme: Computer Aided Slot Allocation CASA, and the FAA National Airspace Performance Analysis Capability NASPAC. EEC NASPAC was modified to be tailored to European airspace caracteristics and is now known as EuroNaspac. The two simulation tools, NASPAC and CASA, were used in a complementary fashion.The two tools working together provided an end-to-end capability to convert the theoretical concept of a traffic flow rate into specific flight-by-flight effects. The SELFLOW and DeliverCtot were responsible for formatting and sending data.

2.2.1 Why NASPAC?

NASPAC reflects the way the FAA approach to congestion which is completely different from the CFMU perspective. The FAA is concerned with congestion problems specifically around airports while, the CFMU is concerned with congestion at any level (airports, en-route sectors). This makes the number of the constraints to resolve larger.

The choice of integrating NASPAC into AMOC was dictated by the following facts:

1. There was no available simulator, at the time, able to deal with data for a large airspace such as the ECAC zone, and to calculate in reasonable amount of time the flight profile and the sectors' loadings.
2. The main objective of the earlier studies was not to produce operationally valid results, but rather to demonstrate the potential of an ATFM simulation capability and to validate the CASA algorithm.

2.2.2 The problems of simulating with NASPAC

Problems arose with NASPAC when the CFMU asked the EEC to prepare contingency plans based on real traffic. Because NASPAC is a prototype simulation of large-scale airspace and air traffic systems, the flight profile calculation is based only on the aircraft performance. Based solely on this information, NASPAC produces mistakes in the en-route sectors loadings. ATC constraints were introduced into NASPAC to model flight profiles more accurate but it's difficult to feed it manually with all the european ATC constraints, and, it is a waste of time when the traffic sample sent to us by the CFMU contains all the information needed (flight profiles based on the aircraft performance, requested level and the ATC constraints and entry time in all the en-route sectors).

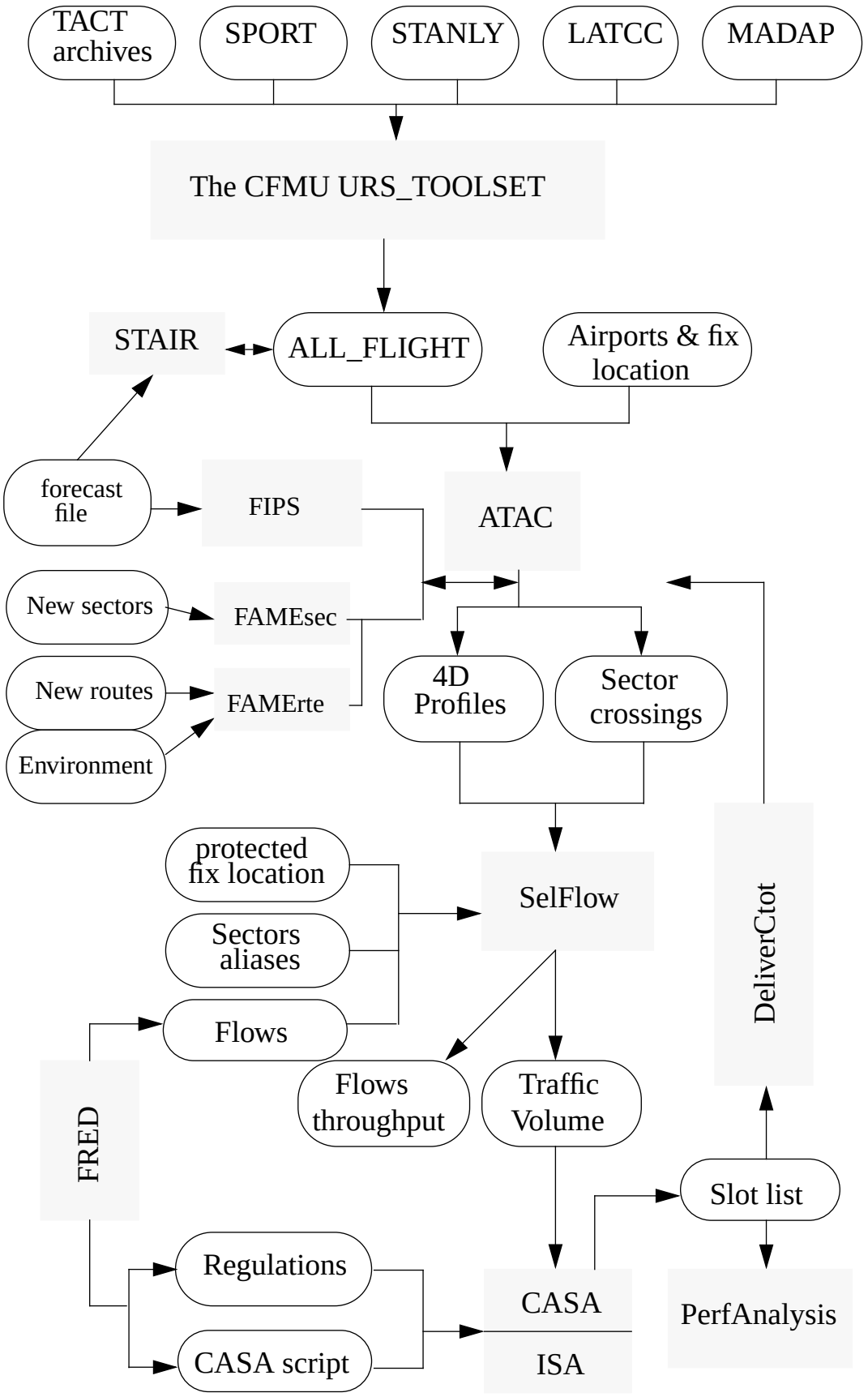
The problems of simulating with NASPAC are sumarized below:

- NASPAC Preprocessor uses about thirty input data files; the simulator engine uses about sixteen differents input data files; and the Postprocessor uses about sixteen differents input data files,
- NASPAC modules are written in different languages: Fortran, Pascal, C, Simscript, Cshell, Dataviews, XView which make it difficult to maintain or improve the NASPAC functions. Moreover, NASPAC is not portable, and runs only on Sun workstation,
- NASPAC uses a linear regression to calculate the en-route time spent between resources. These times depend on the following formula that encompasses uncertainty: en-route time = a*distance^b*r, where r is a mean squared error of the residual which is used by NASPAC to add a random value to the en-route time. Moreover, the values for the regression coefficients are calculated based on data collected from American airlines (which are usually reluctant to publish their data: another doubt about the accuracy of the coefficients).
- NASPAC introduces an implicit delay at all modeled airports by using the airport service time mechanism.
- To model the operations at an airport, a full description of the gaussian curve at that airport should be input.

2.3 The topology of the new AMOC

We found it useful to evolve AMOC functions using CASA as the backbone of our simulation environment, and developing necessary tools around it . This provided two major advantages. First, we gain a significant amount of the simulation time by incorporating a tool that does not recalculate any profile or sector time entrance but only extracts the required information, from the CFMU data, into a readable format for SelFlow. Secondly, we enhance the sectors hourly distribution and thus the plan of regulations by using the same profile and sectors pierced as the CFMU. Thus the studies performed were as close as possible to the CFMU operations.

2.4 AMOC STRUCTURE



The previous figure depicts the high-level architecture of the AMOC Simulator. Few standalone modules interact with each other to provide the basic services that will be described later. AMOC is viewed as a set of hierarchical components collaborating through their interfaces. This document does not address the details about the internal representation of the components.

The above diagram provides a schematic representation of AMOC. From this diagram, we can conclude that it is simple, clean and uncluttered. This hierarchic structure is a major facilitating factor allowing users to focus their attention on the data flow and the way the data are manufactured to achieve a given strategy. Each module can be refined independently or replaced entirely by new software without affecting the AMOC architectrure (it is the principle of “plug and play”). Each module and its individual input and output will be described later.

2.5 Overview of the role of each AMOC parts

It is important to realise that the architecture of AMOC is a function of its component as well as the hierarchic relationships among these components. This rule provides a clear separation of responsibilities among the various components of AMOC, making it possible to study each part in relative isolation.

URS_TOOLSET One of the most important and time consuming task in a fast time simulation is acquiring accurate and timely data. Thanks to the User Requirement Section at the CFMU, we can now use an array of data available at the CFMU through their tool called urs_toolset. The TACT system produces daily archive data at the end of each operational day. This archive contains valuable information about flights, operational events and regulations. There are also several sources of data in Europe used at the CFMU :

- The French SPORT system flight data,
- The German STANLY system flight data,
- The English LATCC system flight data,
- The Maastricht MADAP system flight data.

All these data are converted to a very specific format called ALL_FLIGHT format. The software used for converting these data is a UNIX graphical interface called urs_toolset.

CASA The Computer Aided Slot Allocation is used to enforce the ATFM measures whenever a volume exceeds its projected capacity. It assigns the take-off time for the flights crossing the congested area by comparing their ETOs (Estimated Time Over) and the reference time of the available slots. An overload can occur at the end of the period of activation if no slot is available. The CASA algorithm is a simple heuristic based on the principle of first-planned, first-served.

PerfAnalysis The Performance Analysis module measures the balance between the needs of airspace users to meet their schedules, and the needs of regulators to restrict flow to safely manageable levels. This module analyses the impact of a proposed ATFM strategy in terms of total delay, throughput deviation, regulations redundancy and bunching.

DeliverCtot This module is responsible for updating the crossing times of the en-route sectors, and the times over navaids in the routes of the regulated flights. It extracts the new calculated take-off times (CTOT) generated by CASA algorithm into the SelFlow input files, traject and crossings files.

SelFlow The Flight Selector chooses those flights that meet the criteria of selection of one or more of the regulations and writes :

- the relevant information concerning them in a format readable by CASA,
- the hourly distribution of each defined flow.

To completely describe a regulation, one must specify the airspace to be regulated in terms of flows, the period of activation and the rate at which flights will be accepted. This information is put into several files:

- The period of activation and the rate are put in the “Regulations” file which is an input to CASA,
- The regulated airspace is specified in several ways depending on the complexity of the resulting flow. This description is put in the “Flows” file which is an input to SelFlow.
-

FRED The Flows and Regulations EDitor is a graphical user interface that allows the creation and update of CASA regulations and their corresponding area (flows). It is composed of four panels:

- a panel for defining simple flows
- a panel for defining complex flows (ie logical operations on flows)
- a panel for defining CASA regulations
- a panel for defining the used family of airports.

ATAC The Airspace Traffic dAta Capture is a data generation tool permitting the creation of two input files: traject and crossings. The CFMU TACT system produces archive data at the end of each operational day. These archive data contain valuable information about what happened on that operational day including information about the traffic. The ATAC module reads the traffic file to produce SelFlow input files.

FIPS The Flight Increase Processor Software tool uses DED.4 Traffic Statistics and Forecasts (STATFOR) to generate new flight plans to simulate an operational day in the future. The STATFOR is a flow based traffic growth. With the FIPS tool, you don’t need to run ATAC, because FIPS , as shown in the above figure, works directly on crossings and traject files.

STAIR The Software for CFMU Traffic Analysis and Increase pRocessing is an other tool to generate additional flights directly from the ALL_FLIGHT file. The output of this module is an ALL_FLIGHT file containing the original file plus the extra flights.

FAME The FAst Modifier Environment is a software tool to enforce the changes in the environment(Routes or sectors). It allows the assignment of new routes to certain flights or modification of an old set of sectorisation to a new one. The way FAME will process is simple and can be summarized as follow:

- If the changes affect the sectorisation, FAMEsec will recalculate the sectors time piercing without modifying the 4D trajectories of the flights crossing these sectors,
- If the changes affect routes or both routes then FAMErte will recalculate the profiles and sectors time piercing for only those flights affected by the change in the environment.

2.6 The Incremental and Iterative Nature of AMOC

The process of building an acceptable ATFM strategy for smoothing traffic in congested areas without causing an excessive delay is incremental and iterative. This incremental and iterative nature is evident in the process of elaborating a complete and cohesive ATFM strategy because of the strong coupling between regulations.

Because of this complexity in the flows network, it is not evident to know in advance the number of iterations to converge toward an acceptable ATFM Scheme. As experience accumulates, it turns out that the convergence toward the threshold of stability is around 3 iterations.

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3.0 Using AMOC: Simple steps

This section outlines how AMOC could be used quickly.

3.1 S0. Data Collection

One of the most important and time consuming tasks in applying the ATFM Simulator System AMOC is acquiring accurate and timely data. Our data provider is the CFMU. As outlined earlier in this report, several data sources are available at the CFMU and can be converted to a specific and unique format called ALL_FLIGHT. The acquisition of this file is the starting point of the AMOC utilisation. This file contains valuable information about the flight pattern, i.e. flight callsign, departure and arrival airports, the list of overflown fixes and the list of crossing sectors etc. This format will be discussed further later.

Three files are necessary to start a simulation with AMOC:

- The ALL_FLIGHT file for an operational day,
- The location of all fixes and airports (ICAO location indicator, latitude and longitude),
- A file containing the aliases, or the definition of all subsequent non-elementary sectors. For example, if one wants to use the sector AB, which is a combination of the elementary setors A and B, he should specify it clearly as ‘AB: A B’ or, if one wants to use a preferred name C rather than the name D, he must define it in this file as ‘C: D’.

AMOC does not need the geographical physical location of the used sectors. One can start an ATFM simulation with AMOC without describing the location of the crossing sectors. What is valuable for AMOC is the ICAO name of the sectors, and the time of piercing for all the flights.

3.2 S1. Generate AMOC Input files

The ALL_FLIGHT is processed again by the ATAC module to generate two files:

- traject file containing information about the trajectory of each flight in 4 dimensions. This information relates to the overflown fixes, the estimated time over (ETO) and the altitude.
- crossings file containing information about the en-route sectors for each flight. This information relates to the used sectors, the time of entry and the time of exit.

The ALL_FLIGHT is generated by urs_toolset from an operational day obtained from the Central Flow Management Unit CFMU via network or magnetic tapes . Currently, the process of converting the ALL_FLIGHT data by ATAC needs manual intervention to correct flights with errors, and to enter the locations of missing fixes and airports.

3.3 S2. Sectors Throughput on the Raw Traffic

Once the ALL_FLIGHT file has ben converted, one might run SelFlow to generate the demand for all sectors configuration to get an exact snapshot of what could be hap-

pened if no ATFM measures have been adopted during this operational day or to search for an other ATFM strategy that best fit to the traffic pattern and the airlines schedules.

3.4 S3. Regulation Scheme

Once all the sectors are analysed and the congested ones identified, prepare your regulation scheme to protect overloaded sectors. The AMOC Simulator runs a regulation schema based on centralised flows, decentralised flows, or a mix of both flows. It's up to the strategic planner to decide which approach to adopt in order to smooth the traffic. The strategic decisions taken at this phase have sweeping implications on the final result. The success of the study is dependent on the strategic planner's skill and his ability to deal with the complexity of the traffic network.

3.5 S4. Create Regulations and their correspondents flows

Run FRED to convert your regulation schema into flows definition (input to SelFlow) and their corresponding regulations (input to CASA). FRED also creates a CASA scenario if it does not exist. Once FRED has completed execution, all regulation files are saved to the appropriate CASA input directory.

3.6 S5. Generate Traffic Volume

First, run SelFlow to extract flights belonging to one or several flows. The output of SelFlow is a traffic volume file to be used as input to CASA, and a statistic file concerning flows' demand.

3.7 S6. Slot Allocation

Run CASA by specifying the name of CASA scenario. The outputs of CASA are a trace file containing all slot allocations and update messages, and a report file for each regulation.

3.8 S7. Key Performance Metrics

PerfAnalysis uses the CASA report files to extract the key output metrics. It identifies the redundant or the most restrictive regulations.

3.9 S8. Sectors Throughput on the Regulated Traffic

At this phase, you should inject the new departure times given by CASA (CTOT) into traject and crossings files, and run SelFlow to see the impact of the above strategic decisions on the traffic pattern, and the rippling effect on the non-protected sectors.

3.10 S9. Loop over the process

The Computer Assisted Slot Allocation CASA implements a heuristic search based on a first-planned first-served principle in order to distribute the delays among flights as fairly as possible. However, it does not take into account the dependencies between flows; one regulated flow can generate overload anywhere in the airspace where it is not expected. So, in order to smooth all the traffic, an iteration process is needed. The number of iterations, before the stability threshold, is not known in advance: this

number depends on the distribution complexity of the traffic and the reliability of the regulation schema, (On average, the number of iterations is equal to three for an elaborated regulation schema).

The loop over can start from step 1 (S1) or step 2 (S2) depending on the difficulty and the requirement of the study (centralised or decentralised flows, rerouting ...)

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4.0 How to get the CFMU Data?

As outlined in the AMOC data diagram, the input traffic file to AMOC is an ALL_FLIGHT file which should be processed through ATAC module to get crossings and traject files.

There are several ways to get the ALL_FLIGHT file for a CFMU operational day:

(1) From TACT daily archive data. At the end of the operational day TACT produces an OPLOG file. This file must be processed through the urs_toolset to get the ALL_FLIGHT file,

(2) You can get the OPLOG or the ALL_FLIGHT file for an operational day by asking the User Requirement Section URS of CFMU.

(3) There is a databank of the ALL_FLIGHT files available at the EEC

(4) You can access the ALL_FLIGHT files from the EEC robot.

(5) There is a progressing project called COFEE at the EEC aiming at providing a unique format file to all the EEC simulators. This tool will generate not only a traffic data but also an environment data from the ARC data available at the CFMU.

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5.0 AMOC user tools

As shown in the data flow diagram, the AMOC simulator has a structure of cooperative modules. Each module has its own environment and performs a specific task. They exchange information to present a complete and cohesive system. The design decision was to minimise the tremendous amount of cross-coupling among the components and twisted flows of control which would otherwise threaten the reliability and integrity of the AMOC and certainly obscure the overall clarity of the system.

The goal in designing and connecting individual software modules is to balance the three goals of simplicity, consistency, and efficiency. The design pieces resulting from this approach represent a tighter coupling of data and functionality leading to flexibility in the sense of swift adaptability to changes in problem specifications.

This section describes the components that built the AMOC simulator. The most important part of the simulator is the Computer Aided Slot Allocation CASA.

5.1 The AMOC main window

The figure above shows the AMOC main window. It is the window that appears when AMOC is launched. From this window you are able to access all the components of the AMOC Simulator. The window bar has three different menu titles: Run, Files and Utilities. At the time of writing this report, the functions in the Utilities menus were not yet implemented, only the functions provided by Run and Files menu were accessible.

Through the Run menu you can access all the components described above . In the following sections we are going to briefly show how to run AMOC and its sub-components.

5.2 Starting up AMOC

The AMOC is a UNIX graphical interface. It can be run directly on any UNIX workstation or X-terminal, or on a PC running on X Window configuration. To start running AMOC, open an hpterm window, go to the AMOC bin directory and at the prompt, type “amoc”, then press return.

Now the graphical user interface appears at the top left of your screen.

You can start AMOC remotely from any machine. Below, are described the steps to follow in order to run it remotely.

- add the name of the remote machine containing amoc executable programs as the authorized machines to connect to your display server by typing: xhost + remote_machine
- remote logging onto the machine host where amoc is installed.
- setup the display environment by typing: export DISPLAY=your_display:0.0
- then type: amoc

6.0 CASA

Clearly CASA is the most important element of the AMOC. Its responsibilty is to smooth the traffic in the protected area without underutilising the global capacity. The CASA algorithm is a simple heuristic based on the principle of the first-planned, first-served. But, this principle is not always respected because of the tight coupling among the constraints.

6.0.1 Description of CASA algorithm

For each regulated point, area or aerodrome, CASA constructs and administers a list of slots called the slot allocation list. A regulation may be divided into sub-periods, each sub-period being assigned a rate. CASA uses these items initially to construct an empty slot allocation list. For instance, a four-hour sub-period associated with a basic rate of 28 flights per hour, would result in a slot allocation list made up of 112 slots separated from one another by approximately 2 minutes.

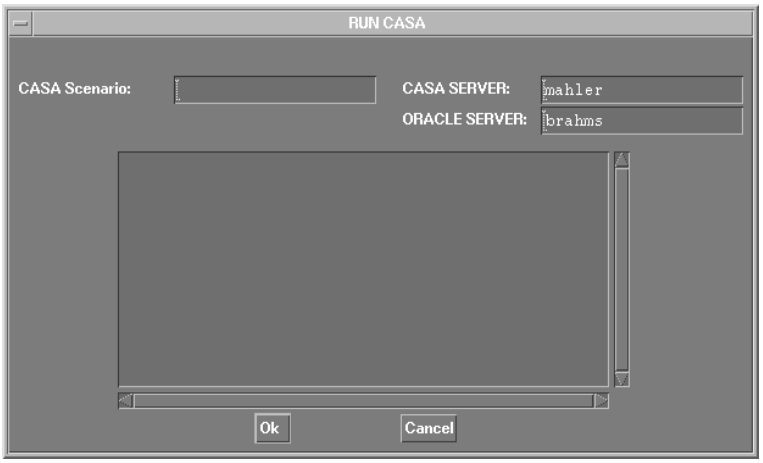
Each flight is given a provisional slot based on the order of its Estimated Time Over (ETO) the restricted area and the reference time of the closest slot. This initial reservation is internal to the system and is subject to amendment.

When CASA receives new flight data, it tries to pre-allocate the slot that best fits the requested Estimated Time Over (ETO) the reference point of the flow-controlled zone.

- if that slot is free, it is assigned to the flight, which thus suffers no delay
- if that slot is already pre-allocated to a flight which is planned to overfly the restricted location after the new flight, then the later flight takes the slot. Of course, the consequence can be a chain reaction, because the flight whose slot has been taken tries to recover another slot, possibily by taking the slot of another flight, etc.
- if that slot is already allocated, it cannot be taken by a flight candidate for preallocation.

6.0.2 Running CASA

The first thing you may have to do is to run AMOC if it is not already done. Once the AMOC main window appears on the top left corner of your screen:



- Select the menu item **Casa** from the **Run** menu.
- In the window that appears, click and enter the name of the CASA scenario to run. The CASA scenario is the name of the directory where all the required input files are. If the name of your CASA scenario is “test”, the input files are under “*/net/CASA_SERVER/users/casa/casa07/test*”. The CASA SERVER will be explained below.
- In the CASA SERVER textbox, enter the name of the host machine where the CASA executable files are installed.
- In the ORACLE SERVER textbox, enter the name of the host machine where the CASA Oracle Database is installed.
- Click onto the **Ok** button to activate the execution of CASA or the **Cancel** button to close the window without running CASA.

When CASA is running, the window is closed and all the information about the status of CASA execution is displayed on the hpterm window from where you launched AMOC. Once CASA finishes its execution, the window appears again. Click onto the Cancel button to get rid of it.

6.0.3 CASA input files

CASA (mode SIMCA) takes three files as input data files. Multiple versions of these files are maintained to describe differents ATFM strategies.

The Traffic Volume file: This is the input file, generated by SelFlow, to CASA. Each line is a message to CASA identifying the flight (callsign, take-Off time, list of regulations names and their corresponding time over). In the real world, the CFMU TACT system receives its input from STRAT (flight data known long in advance) and IFPS (flight data known at the day of the take off, or the day before). The TACT System

compares air traffic demand with ATC capacities. Whenever demand is projected to exceed capacities, TACT selects flights and sends them to CASA. In our study here at the EEC, the data supplier is SelFlow.

The file is a sequence of line of the following format:

(change_flight_data <flight_data> <concerned_regulations>)

The following two sections describe , respectively, the format of flight_data and concerned_regulations.

flight data format

ITEMS	COMMENTS
<category>string	one of the strings [PLAN_DATA, AIRBORNE_DATA, CANCELLATION, SRR]
<external_message>boolean	indicates if the input to CASA is caused due to an external message ie a message coming from the AO or an internal message ie a regulation activation
<flight_reference>format	unique identifier of the flight
<aircraft_id>string	call sign
<flight_origin>string	one of the strings [RPL, PFD, IFPL]
<late_filer>boolean	
<late_updater>boolean	
<general_exempted>boolean	
<confirmed_flight>boolean	
<EOBT>big_time	
<ETOT>big_time	
<atot>big_time	

Below, is a description of flight data for a given flight with “AFR5342” as the callsign and 1 as the aircraft identifier (The aircraft identifier is an internal number that distinguishes the flight and resolves the problem of flights using the same callsign). This flight is not a late filer, late updater and it is not exempted from all the crossing regulations. The day of departure of this flight is 970205 (5 February 1997)

PLAN_DATA
T
1
“AFR5342”
IFPL
F
F
F
F
“970205075500”
“970205080000”
nil

list of concerned regulations format

A list of concerned regulations has the following format:

(

<regulation_reference>	; It is the name of the crossed regulation
<estimated_time_over>	;It is of the type “YYMMDDhhmmss>
<actual_time_over>	;It is of the type “YYMMDDhhmmss”
<exempted_flag>	; It is a boolean flag and takes F or T value

)

Note: YY : the year in 2 digits; MM : the month in 2 digits; DD : the day in 2 digits; hh is the hour in 2 digits; mm : is the minutes in 2 digits; ss : the seconds in 2 digits.

Overleaf, it is a description of the list of concerned regulations. In this example, the concerned regulations are rUGW and rUH which protects respectively the sector UGW and UH.

```
(
rUGW
“970205100000”
nil
F
rUH
“970205103000”
nil
F
)
```

6.0.4 CASA regulations file

A regulation definition must have the following format :

(local_construct <variable_name> <regulation>)

The local_construct will create a local regulation (i.e. the regulation is created in the memory but it is not stored in the database) and will put this local regulation in the variable named variable_name.

The format for <regulation> is explained below via an example:

```
(rUGW                                ; regulation name
TFrUGW                               ; traffic volume name
“970204200000”                       ; process start time
(“970205060000” “970205180000”)      ; regulation period of activation
F                                    ; Is flight confirmation needed ?
15                                   ; window width
20                                   ; slice width
T                                    ; Is it a temporary regulation ?
“note for regulation”                : comments
;;thresholds
60                                   ; maximum flight delay
10                                   ; maximum flights at the  period end
                                       slots
30                                   ; slice overload pecentage
35                                   ; segment delay
15                                   ; unused segment slot percentage
25                                   ; segment overload slot percentage
```

```
30                                          ; time band equity
;; a list of subperiods.
;; The 3 inner elements - period, normal
rate, pending rate - can be repeated
(
("970205060000" "970205180000") 10  2
)
;; a list of timeband width
;; to have a correct regulation, last element
must be > 1440.
(120 180 2000)
;; a list of timeband allowance subperiods.
;; The 2 inner elements - period + allow-
ances - can be repeated.
;;the normal_rate_percentage +
pending_rate_percentage
;; must be repeated for each timeband width
(
("970205060000" "970502180000")
(34 34
33 33
33 33)
)

;; a list of supplementary subperiods. Note:
list can be nil
;; the 2 inner elements - period + supple-
mentary rates - can be repeated.
nil
)
```

6.0.5 CASA Script file

The script file is a text-based file. It contains a set of service calls that will be routed to the regulation package in order to perform a specific task.

A service call is a process that will trigger a well-defined action. Each service call is preceeded by opening parentheses, terminated with closing parentheses and may have asociated parameters.

Only a few services calls are used for running CASA into AMOC. It should be noted that the scope of service calls used at TACT level is very large. Below we will describe the purpose of each service call we use.

(1) (trace <boolean> <boolean>)

Trace is used to enhance the output of CASA. The first field of this service instructs CASA whether or not to print the result of each service. The second field instructs CASA whether or not to print full details of each service encountered, along with the full associated parameter list.

(2) (continue_on_error <boolean>)

This service is used to affect the behaviour of CASA in response to failure conditions. If a service fails, either through script syntax errors or CASA application rejects the requested action, a flag is set by CASA to control the continuation of the process. If the boolean is False, CASA will continue execution, otherwise it will stop in case of any sevice call failure. By default the continue_on_error flag is set to false.

(3) (auto_end_of_list <boolean>)

The purpose of this service is to avoid having to call the “end_of_list” after each regulation activation. When a regulation is activated, the flights concerned by this new regulations must be passed to CASA using the service change_flight_data. During the activation of a regulation, the allocation of slots is slightly different. It is thus required to indicate to CASA that the initial list of flights is terminated. This is done using the end_of_list service

(4) (initialise <boolean> <“yymmddhhmmss”>)

This service is used to initialise the regulation package.

(5) (set_server)

This service is used to initialise the regulation package in server mode.

(6) (call <file_name>)

This service groups several service calls in a file and execute them in one call.

(7) (create <regulation_name>)

This service is used to create a regulation. After the creation, the regulation will be taken into account by CASA. The regulation_name must be the same as the one used in local_construct call service.

(8) (time_control <“yymmddhhmmss”> <step>)

This service manipulates time within CASA system

(9) (start_test)

This service prompts the Ada Test Harness to start a test.

(10) (execute <“test”>)

This service indicates to the Ada Test Harness that a test is about to be started.

(10) (done)

This service indicates to the Ada Test Harness that some check services are to be called.

(9) (report <regulation_name> <boolean> <file_name>)

This service indicates to CASA that a report should be produced for a defined regulation. If the <boolean> flag is True (T), a report is generated for the regulation, and the ouput file is <file_name>. If the <boolean> flag is False (F), no report is generated. In AMOC context, the report service is called for all regulations with the <boolean> flag set to T.

An example of a CASA script is described below:

(trace T F)

(continue_on_error F)

(auto_end_of_list T)

(initialise T “970201200000”)

(set_server)

(call “make_regul_rUGW.1997”)

(call “make_regul_rUH.1997”)

(create rUGW) ; if it is not already done in make_regul_rUGW.1997

(create rUH) ; If it is not already done in make_regul_rUH.1997 file

(time_control “970201235900” 5)

(start_test)

(execute “test_1”)

(done)

(call “make_flights.el”)

(report rUGW T reportUGW.1997)

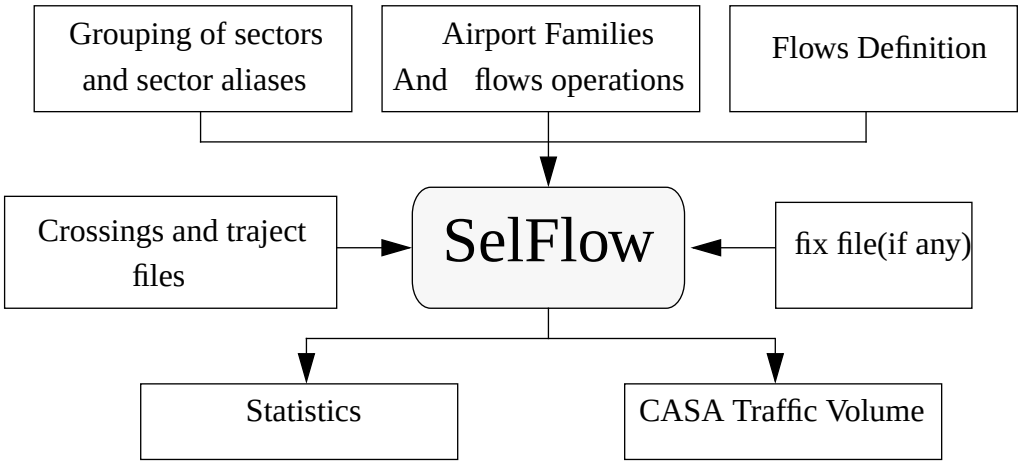
(report rUH T reportUH.1997)

INTENTIONALLY LEFT BLANK

7.0 SelFlow

CASA works in passive mode. It receives information about flights and the regulations, and tries to assign a slot to each flight according to its ETO. It does not know in advance which flights to regulate or which flows to be protected. This is the responsibility of SelFlow.

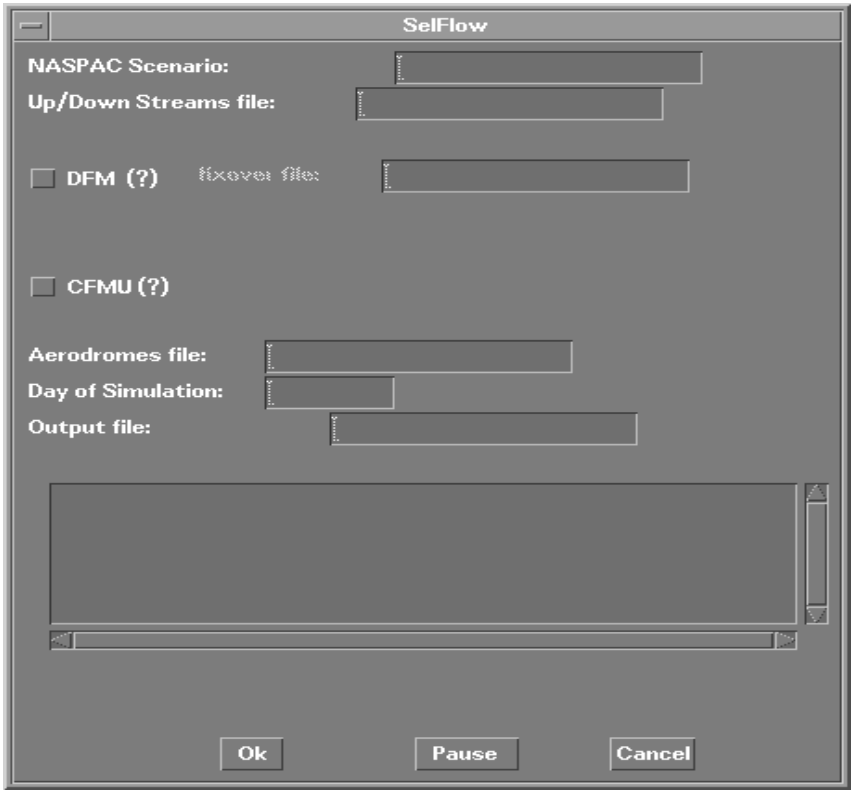
SelFlow was specified with close collaboration with operational staff involved in the ATFM study. The aim was to help regulators in identifying the mainstream flows and applying regulations. It selects the flights that comprise flows through regulated parts of the airspace at specified times. Its basic functionalities can be grouped in four categories:



- Creation Phase : we create empty flows objects, airport families and protected volumes based on the definitions made by the regulators.
- Extraction Phase: we only select flights belonging to one of the created flows, and departing from or arriving to, one of the airport families, and crossing or overflying one or several protected volumes.
- Processing Phase: the sectors are described as elementary entities to allow the regulators freedom to adapt the airspace configuration to the traffic and the availability of the controllers. Thus, a dynamic restructuring of the airspace in the process is taken into account. SelFlow also prepares flights that would be exempted by CASA.
- Merging Phase: It gives the flexibilty to merge in the same process run, centralised and decentralised flows.
- Formatting Phase: SelFlow formats information about flights under regulations into file for use by CASA.
- Statistic Phase: SelFlow generates statistics demand for all defined flows along their lifetime.

7.1 Mode Of SelFlow Use

The first thing you may be required to do is to run AMOC if it is not yet done. Once the AMOC main window appears on the top left corner of your screen.



Select the menu item **Selflow** from **Run** menu, the Selflow main window will be opened, as shown in the figure above. In this window you are able to set up the input files for Selflow. These include the following.

The traffic scenario corresponds to the extension name for traject and crossings files.

The Up/Down Streams correspond to the file containing the definition of the specified flows.

The DFM button enables you to run a simulation with protection over fixes. You should turn it on only when fixes are taken into account in the regulation scheme. Once this button is selected, you must enter the name of the file containing the name of protected fixes, andthe minimum and maximum levels which apply to an overflying flight subject to this regulation.

The CFMU button enables you to run a simulation with protection over sectors.

The aerodromes file is the name of the file containing the definition of aerodrome family and the logical operations over flows.

Day of Simulation corresponds to the operational day being simulated. It takes the following format “yymmdd” where “yy” is the year, ‘mm’ is the month and ‘dd” is the day.

Output file corresponds to the name of a file which will contain the output of SelFlow. This file will be used by CASA.

Once all the textboxes contain the values you require, you can run SelFlow by clicking onto “Ok” button or dismiss it by clicking on “Cancel” button.

7.2 Sectors aliases file

The grouping of sectors and aliases file contains attributes describing all grouping of sectors, including aliases. An alias is an abbreviation of a long name or a preferred name to the ICAO one. For example, French regulator tend to call the sector “LFM-MCO” by the short name “CO”. Also a group of sectors is considered as an alias because the grouping of a set of adjacent sectors is treated as if the resulting area was a single sector with geometric boundaries composed of the outermost external boundaries of the individual sectors; The time of piercing of its boundaries is the time of piercing of the first sector. The alias and the grouping of the adjacent sectors mean,, in SelFlow context, the same thing and so we will use them interchangeably. SelFlow by default uses a file called “sec.grp”. So, if you want to add or modify an alias, you should do it in the sec.grp and save it.

The file has the following format:

<number_of_aliases>

<list_of_aliases>

Examples:

Suppose that we want to use a sector AB as the group of the elementary sectors A and B. One can define it as follows AB: A B

Suppose again that we want to create the name CO instead of the name LFMMCO. One can define it as follow CO: LFMMCO

7.3 Aerodromes file

Description: This file contains the definition of all the airport families used in the flows description and the logical operations on flows. This file is subdivided into two paragraphs, one paragraph for the definition of the airports families and the second one for the definition of the logical operations on flows.

Families paragraph: A family is a set of related airports within or outside the simulated area. It consists of a name that uniquely identifies the family and a list of airports. The format of the families paragraph is as follow:

nb_of_families				
family1	nb_of_airports	aiport11	...	airport1i
...	...	...	...	
familyN	nb_of_airports	airportN1	...	airportNj

(1) <nb_of_families> is the number of families used in the families paragraph, this number occupies the first line on the file.

(2) there is a line for a definition of each family, it consists of fields separated by blank(s):

(2.1) the first field <family> is the name of the family,

(2.2) the second field <nb_of_airports> is the number of airports belonging to the family,

(2.3) a list of airports composing the family.

NB: No blank line is permitted in this families paragraph.

Example: Suppose that in a specified study we are interested in only two airports families. The first family is all the airports within France called FRANC. The second family is all the 'North Atlantic' airports called NATS.

The families paragraph will contain the following definitions :

```
2
FRANC   1   LF**
NATS    7   B***  T***  C***  K***  M***  S***  P***
```

Logical operations on flows paragraph: A logical operation on two flows consists of a set of operations stated under the classical form of propositional logic**:**

- OR operation: It consists of summation of all flights belonging to the two flows.
- AND operation: It consists of selecting only the flights belonging to both flows, This is important when we are interested in a flow over a segment of routes, or a flow crossing a sector and overflying a fix.
- Excluding operation: It consists of excluding from one flow another flow. Only the flights belonging to the first flow and not to the second remain. It's important when we want a specified flow crossing a protected volume to be freeflow.

The format of the logical operations paragraph is of the following form:

```
nb_of_flows
FLOW12      =    FLOW1     op   FLOW2
...         ...  ...       ...  ...
FLOWij      =    FLOWi     op   FLOWj
```

(1) <nb_of_flows> is the number of the logical operations on flows. This number must be written just after the families paragraph without any blank line. If no logical operations are specified, you must write 0 meaning zero operation.

(2) There is a line for the definition of each operation, it consists of fields separated with blanks:

(2.1) The first field is the name of the resulting flow,

(2.2) The second field is the mathematical equal sign,

(2.2) The third and the fifth fields are the name of flows defined in the flows file (explained in the next section),

(2.3) the fourth field is the identifier of the used operation. There are 3 kinds of operations: + for the OR operation, & for AND operation and - for the excluding operation.

Examples

Example1: Suppose that we are interested only in the traffic flowing between two adjacent fixes: fix A and fix B.

In the flows file, you must define two flows: the flow overflying fix A and another flow overflying fix B. Once these two flows have been defined, you must define the resulting flow from flowA and flowB as : flowAB = flowA & flowB

This means that SelFlow will first extract the traffic subject to flowA, and traffic subject to flowB, and afterwards, it will keep only the traffic present in both flows as flowAB.

Example2: Suppose now that we are interested only in the traffic crossing sector SEC and not overflying fix A.

In the flows file, you must define two flows: the flow overflying fix A and another flow for the traffic crossing sector SEC. Once these two flows have been defined, you must define the resulting flow from flowSEC and flowA as : flowSECA = flowSEC - flowA

This means that SelFlow will first extract the traffic subject to flowA, and traffic subject to flowSEC, and afterwards, it will keep only the traffic present in flowSEC but not in flowA as flowSEC-A.

7.4 Flows file

This file contains the description of the specified flows. A flow consists of upstream, downstream elements and a volume. Upstream elements are describing an origin area, downstream elements are describing a destination area.

An upstream/downstream element can have an exception list which is a set of excluded airports.

A volume is a set of sectors and/or fixes. A volume is not mandatory but can be present in the definition of a flow.

You should remember that all the volumes used in the description of a flow are aliases and should be defined in the aliases file, unless the volume is an elementary sector or a single fix.

The format of a flow is as follows:

<dep_family>{exception_list}.<arr_family>{exception_list}[^volume]
nb_of_flows
<flow_name1> 1 <start_of_period> <end_of_period>
...
<flow_nameN> 1 <start_of_period> <end_of_period>

(1) The <dep_family>/<arr_family> is the name of a set of airports. The family name must be defined in the aerodromes file unless it is a single airport, a centre (all airports belonging to the centre) or a country as whole.

(2) The <exception_list> specifies the set of airports to be excluded from the family of the airports.

(3) <volume> specifies the part of the airspace to be protected. The volume is not mandatory and if it is not present then the protected area is the dep_family.

(4) nb_of_flows specifies the number of the sub-flows. Suppose that you want to protect a volume from 07:00 to 10:00 and from 12:00 to 18:00. As CASA does not accept non contiguous intervals, you must define 2 sub-flows, one sub-flow for each interval.

(5) flow_name identifies the name of the flow. This name will be used later as the name of the CASA regulation.

(6) start_of_period and end_of_period specify the start and end of the activation period. SelFlow will be used to extract flights whose ETOs fall within this period and CASA will use this period with a corresponding capacity to allocate slots.

Example1: Suppose we want to regulate all the traffic coming from LFPO, going to LFMN and crossing the sector UGW between the period 08:00 and 18:00. First, you must define the flow and give it a name. The name of this flow will be rUGW. The definition for this flow is as follows:

LFPO.LFMN^UGW
1
rUGW 1 480.0 1080.0

The departure and arrival family are single airports so you don’t need to define them in the aerodrome files. You can if you want but it will be a redundant definition because SelFlow understands the concept of single airports.

Example2: Suppose that we are interested in departures from FRANCE, going to the North Atlantic between 18:00 and 20:00. We can see that the only volume of interest in this abstraction is the departures from the French airports to the North Atlantic regardless of which sectors are crossed. This flow will be called FRANC>NATS for departures from France to NATS. Below we show some steps to define this flow:

First, you must describe in the aerodromes file what are the north Atlantic airports, and what are the French airports. In this paper, we will give to the French airports the global name FRANC, and NATS to the North Atlantic airports.

Second, in the flows file you must define the flow as follows:

```
FRANC.NATS
1
FRANC>NATS    1    1080.0   1200.0
```

In the aerodrome files, you will define the two families of airports:

```
2
FRANC     1       LF**
NATS      7       B***    T***    C***    K***     M***     S***     P***
```

Explanation: 2 means that the aerodrome file contains two families of airports. Each line contains the definition of one family of airports which consists of the name of the family, the number of the elements of the family and the name of each element of the family in the rest of the line.

Note: It's better to generate the Flows file with Fred tool. It is a graphical user interface that allows the creation of the flows and their corresponding regulations. The use of Fred will be explained later.

7.4.1 Centralised flows

A flow is defined as a centralised flow when upstream and downstream elements are defined as a whole world and the volume is not present at all or constructed only with sectors. This definition is generalised even to specialised upstream/downstream

7.4.2 Decentralised flows

A flow is defined as a decentralised flow when the volume contains at least one fix.

7.4.3 Operations on Flows

The discussions with the regulators about flows brought three set of operations stated under the classical form of propositional logic:

- OR operation: It consists of summation of all flights belonging to the two flows.
- AND operation: It consists of selecting only the flights belonging to both flows, it's important when only a flow over a segment of routes, or a flow crossing a sector and overflying a fix, is in the interest.
- Excluding operation: It consists of excluding from one flow another flow. Only the flights belonging to the first flow and not to the second remain. It's important when we want a specified flow crossing a protected volume to be freeflow.

7.5 Volume

A volume is built from a fix or sector(s). The volume is defined by a single name. It could be the name of a fix, an elementary sector or an alias. If an alias is used, you must define it into the alias file unless it's already done. If a fix is used, you must define it in the fix file. Here is a description of the way the volume can be defined:

- Fix The location of a point is defined by its latitude and longitude, and by the part of airspace enclosed between the base altitude and ceiling altitude.
- Sectors The only information needed is the sector name. The sector can be the name of an elementary sector or an alias.In this case it should be defined in the aliases file.

Example

We want to define a flow comprising traffic crossing the sectors UA, US, UG1,UG2,UG3,UW1,UW2, UW3. First, we have to define an alias UGWS which is the parent to all the above elementary sectors. This definition will be put in the alias file sec.grp; The resulting volume which will be used in the definition of the flow is UGWS.

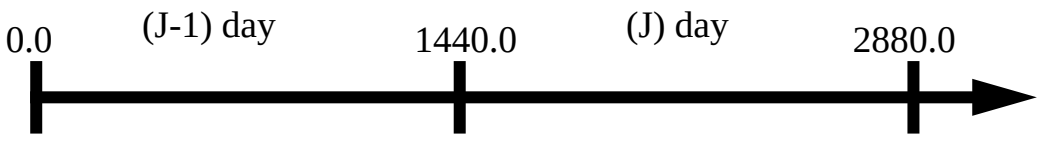
7.6 Flow Period

A flow period is the interval during which the flights belonging to that flow are extracted. The extraction is based on the following criteria:

- if the volume is present, a flight is considered to belong to the flow when its departure airport belongs to the flow upstream, and its arrival airport belongs to the flow downstream, and the time of volume crossing is inside the flow period.
- if the volume is not present (regulation by departure aerodrome), the criteria of extraction are the same as above, except that a flight is considered to belong to the flow when its departure time is inside the flow period.

The start and end times of the activation period are expressed in minutes, starting from the first day of the simulation. To simulate the J day, we usually need the traffic for the (J-1) day.

The start time simulation for the J day is 1440.0 (= 24 * 60) and the end is 2880.0 (= 24*120).



The use of decimal point is for enabling the seconds. You must convert the seconds into a fraction of minutes.

7.7 Fix file

This file is used only when one of the protected volumes is, or contains a fix. The format of the file is very simple:

fix_name latitude longitude floor ceiling

Example: MOPUG needs to be protected between FL070 to 250, and from FL250 to unlimited. Two differents points have to be created:

MOPUG1 461000 -0204200 70.0 250.0

MOPUG2 461000 -0204200 250.0 999.0

7.8 Traffic file and how it is processed

SelFlow reads two files from the same directory: For fix based regulations, it uses the traject file that contains the routes of scheduled traffic in 4 D format (latitude, longitude, altitude and ETO). For sectors based regulations or airport based regulations, SelFlow uses the crossings file which contains information about the crossed sectors and the time estimated over. Both files are generated by ATAC module from the ALL_FLIGHT file for a defined operational day.

You must remember that both files contain information about the traffic for two days: the previous day and the day of the simulation. Thus, the simulation time lasts from 0 minute to 2880 minutes:

(1) The traffic corresponding to the previous day starts at 0 min. and ends at 1440 min,

(2) and the traffic for the operational day starts at 1440 min and ends at 2880 min.

The need to have both the previous day and the operational day is to take into account the flights departing the previous day and arriving on the operational day.

7.8.1 Traject file

Descriptions: This file contains the climb/cruise/descent profiles for all the simulated flights. It includes the ETO and altitude at each overflown fix.

Data Record 1: Aircraft Information.

Column	Format	Contents
1-5	Integer	Aircraft identifier
6-8	Alpha	Aircraft operator
9-12	Alpha	Aircraft type
13-13	Integer	Equipment category
14-14	Integer	Enroute time category
16-17	Integer	Number of legs

Data Record 2 : Airports Information. This record describes the departure and arrival airports, plus the time of departure and arrival, and the ground delay incurred by the flight. This record is repeated Number_of_legs time.

Column	Format	Contents
1-5	Alpha	flight ID
6-9	Alpha	Departure Airport
11-14	Alpha	Arrival Airport
15-22	Real	Departure Aiport latitude (decimal degree)
24-31	Real	Departure Airport longitude(decimal degree)
33-36	Integer	Departure time (in minute)
37-44	Real	Arrival Airport latitude (decimal degree)
46-53	Real	Arrival Airport longitude (decimal degree)
55-58	Integer	Arrival time (in minute)
62-63	Integer	Delay (in minutes)
66-68	Integer	Azimuth
70	Char	Direction
72	Char	Flight Plan Completeness
75-76	Integer	Number of fixes in the route

Data Record 3: Routes Information. This record describes the route that links the two airports. This record is repeated Number_of_fixes time.

Column	Format	Contents
1-2	Alpha	Always RP
3-7	Alpha	Fix name
8-15	Real	Fix latitude (decimal degree)
17-24	Real	Fix longitude (decimal degree)
26-28	Integer	Fix altitude
30-37	Real	Estimated Time Over

7.8.2 Crossings file

Descriptions: This file contains the crossed sectors for all the simulated flights. It includes the ETO for each crossed sector. The information here is the same as that used in the traject file

Data Record 1: Aircraft Information

Column	Format	Contents
1-5	Integer	Aircraft identifier
6-8	Alpha	Aircraft operator
9-12	Alpha	Aircraft type
13-13	Integer	Equipment category
14-14	Integer	Enroute time category
16-17	Integer	Number of legs

Data Record 2 : Airports Information. This record is repeated Number_of_legs time. It describes the departure and arrival airports, plus the time of departure and arrival, and the ground delay incurred by the flight. It is slightly different from the Data Record 2 describe in the traject file.

Column	Format	Contents
1-5	Alpha	flight ID
6-9	Alpha	Departure Airport
12-15	Integer	Departure time (in minute)
16-19	Alpha	Arrival Aiport
22-25	Integer	Arrival time (in minute)
29-30	Integer	Delay (in minute)
33-35	Integer	Azimuth
36	Char	Direction
37-38	Integer	Number of crossed sectors

Data Record 3: Sectors Information. This record describes the en-route sectors. This record is repeated Number_of_crossed_sectors time.

Column	Format	Contents
1-2	Alpha	Always SC
3-8	Alpha	Sector name
9-14	Real	Estimated Time Over (in minute)
16-20	Real	Flying time in the sector (in minute)
22-26	Real	Flying time to the next sector or ades

7.8.3 Processing

SelFlow reads the traffic file into memory and compares each flight to the appropriate flow, then either stores the flight in the output file in a format readable by CASA or discards it. A flight belongs to a flow only if:

- the departure airports is in the list of the departure families, AND
- does not belong to the list of the departure exceptions, AND
- the arrival airports is in the list of the arrival families, AND
- does not belong to the list of arrival exceptions, AND
- there is a common airspace between the list of fixes or sectors crossed by the flights and the flow volume, AND
- the expected time over the common airspace is after the start time and before the stop time of the flow. For reasons related to the inability of the CASA version 1.4 to deal with the collapsed sectors, the start time of each flow is adjusted to 1 hour before flow start time, and the stop time one hour after flow stop time automatically by SelFlow.

You should also remember that the maximum of the regulations one flight can be subject to is limited to 10 regulations in CASA mode Simca and 15 in CASA mode TACOT.

7.9 Statistics

SelFlow generates hourly statistics about all the defined flows. These statistics are used later to determine for which period of the day a flow needs to be regulated. The statistics are not limited to elementary sectors but are extended to any kind of volumes:

- Departure airports

- Departure/Arrival airports

- Family of departure/arrival airports

- Segment of a route

- Navaids

- Groups of sectors

Example: Below, are hourly statistics for global movement (departures and arrivals) in some European airports.

The field separator is colon ":" , thus you can process the statistics file with Excel for producing charts.

Flows	**Hourly distribution from 0 to 23**
LEMDGLO:	6 : 7: 5: 2:14:38:53:55:59:47:44:36:45:37:33:46:50:51:53:48:34:24: 5: 5
LEPAGLO:	6 : 7: 7: 7:10:34:28:33:23:17:20:21:33:21:18:26:29:24:44:30:29:18:11:10
LGTSGLO:	1 : 1: 1: 2: 3: 5: 7:12: 7: 5:11:10: 7: 9: 9:10: 7: 5: 1: 5: 5: 2: 2: 2
LGATGLO:	3: 5: 9:19:14:30:35:29:25:25:25:21:38:26:34:25:19:24:16:11:12: 7: 3: 2
LGIRGLO:	3: 1: 0: 1: 2: 2: 7: 6:14: 6: 7: 7: 6: 7: 9:11:10:10:14: 5: 5: 6: 3: 7
EBBRGLO:	3:14:13: 1:10:36:58:47:71:36:36:55:33:49:35:49:51:64:43:32:25:13:20: 5
EDDBGLO:	3: 2: 2: 6: 6: 5: 3: 5: 7: 4:11:11: 6: 5: 6: 4: 2: 4: 2: 6: 6: 3: 5: 7

7.10 Log file

This file contains valuable information that can be used to link the flights regulated by CASA and their origin-destination. Thus, statistics modules can be coded for example to produce total delay per departure aerodrome, arrival aerodrome or both. The traffic volume file sent to CASA does not contain the city pair for the regulated flights.

Column	**Format**	**Contents**
1st column	Integer	Aircraft ID
2nd column	Alpha	Call sign
3rd column	Alpha	Departure airport
4th column	Integer	Departure time
5th column	Alpha	Arrival airport
6th column	Integer	Arrival time

Column	Format	Contents
7th column	Alpha	Regulation ID
8th column	Integer	ETO

NB: the 7th and 8th columns can be repeated if there are other regulations
.

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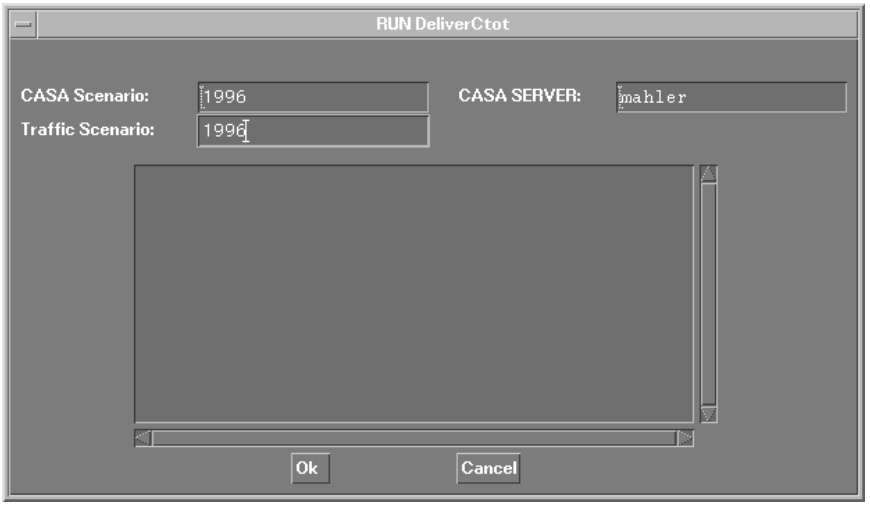
8.0 DeliverCtot

The output of CASA is a very large trace file that contains valuable information. This information concerns the creation of the regulation, the allocation of slot for each flight and all the updates.

The purpose of DeliverCtot is to extract the calculated take-off times (CTOT) from this file and inject them into traject and crossings files. It stands downstream from CASA and upstream from SelFlow.

8.1 Running DeliverCtot

The first thing you may be required to do is to run AMOC if it is not yet done. Once the AMOC main window appears on the top left corner of your screen:



- Select the menu item **DeliverCtot** from the **Run** menu.
- Enter the CASA Server. By default, the casa server is mahler; and you should modify it if the CASA executable files and scenarios are placed elsewhere.
- In the window that appears, click and enter the name of the CASA scenario, and the extension for the traffic file (traject and crossings files to be updated).
- Click onto the **Ok** button to activate the execution of DeliverCtot or **Cancel** button to close the window without running DeliverCtot.

When DeliverCtot is running, the window is closed and all the information about the status of DeliverCtot execution is displayed on the hpterm window from which you have launched AMOC. Once DeliverCtot finishes its execution, the window appears again. Click onto the cancel button to get rid of it. If no problems are encountered during execution, DeliverCtot will produce new traffic files: crossings.<new_extension> and traject.<new_extension>

8.2 Input

The CASA output file used by this program is called “temp”, so the pathname used by DeliverCtot to access this file is “/net/casa-server/users/casa/casa07/casa_scenario”. At the time being the casa-server is “mahler”. The program extracts the lines of this file

that are relevant to generation of CTOTs, and stores the information by flight. The CASA output file may contain many CTOT messages per flight, in such case only the last CTOT is taken into account. Two other files are used by DeliverCtot are crossings.<extension> and traject.<extension>

8.3 Output

The output of the program is the traffic file (traject and crossings files) that differs from the original only by having the departure times generated by CASA. DeliverCtot applies the delay occurred by a defined flight to all the resources used by that flight (fixes, sectors)

IMPORTANT: The traject.<new_extension> and crossings.<new_extension> must be injected again into SelFlow to show the effect of the ATFM measures on non-regulated parts of the airspace.

IMPORTANT: If all the sectors were regulated, then there is no need to run DeliverCtot because CASA takes care of smoothing the traffic in all the protected area.

IMPORTANT: The <new_extension> is equal to <extension_update>. If the original traffic files are crossings.1996 and traject.1996, then the new updated traffic files are crossings.1996_update and traject.1996_update.

8.4 How DeliverCtot processes

DeliverCtot reads from temp file the delays generated by CASA and uses the aircraft id and leg id extracted from this file to find the flight to which the delay must be injected. The DeliverCtot changes the times in flight header and course points and outputs the updates into two new traffic files: crossings.<originalextension_update> and traject.<originalextension_update>.

9.0 PerfAnalysis

Performance analysis (PerfAnalysis) module is developed to extract key output metrics from CASA reports. This module measures the performance of ATFM strategies applied on a defined traffic with a defined airspace configuration in terms of:

- Total Ground Delay
- Average regulated flights
- Average constrained flights
- Maximum delay
- Number of regulated flights
- Number of constrained flights
- Number of flights with delay greater than one hour
- Number of flights with delay between half an hour and one hour
- Number of flighs with delay less than 15 minutes
- And for each regulation:

1. The total delay imposed by that regulation
2. The number of unused slots
3. The number of overloaded slots

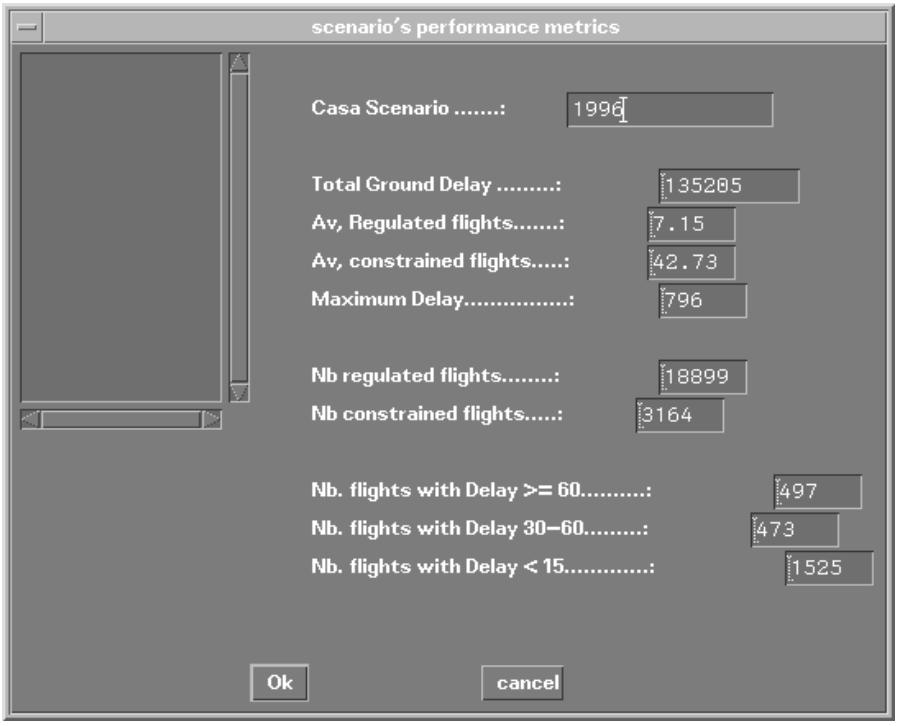
These key output metrics enable the regulators to: choose the ATFM strategy that best fits the traffic and the airspace configuration; to adjust the ATFM measures in order to diminish the number of combined flights; or to remove the redundant regulations (protected upstream/downstream by others regulations).

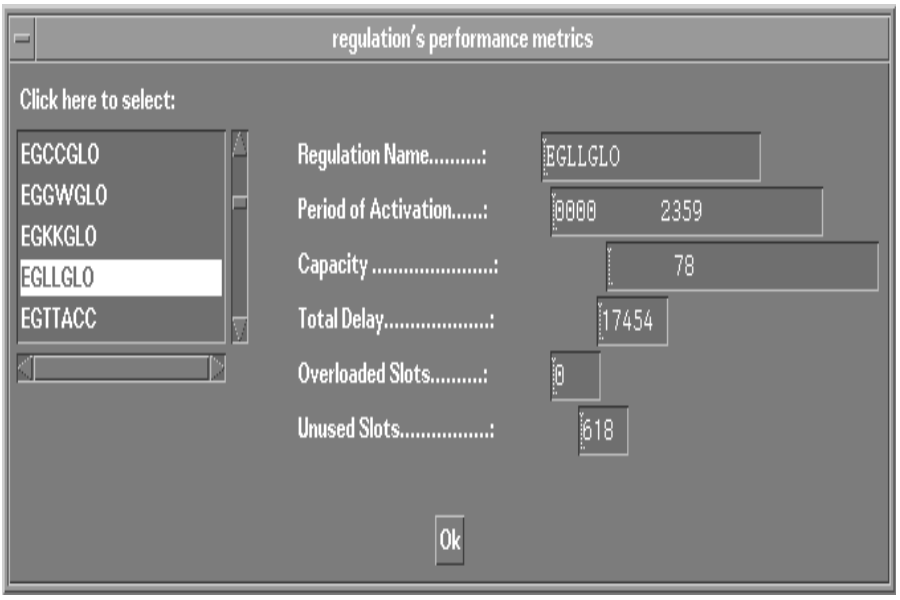
9.1 Running PerfAnalysis

From the AMOC main window:

- Select the menu item "**Performance Analysis**" from the **Run** menu
- In the window that appears, click and enter the name of the CASA scenario to be analysed.
- Click onto the **Ok** button to activate the PerfAnalysis or **Cancel** button to close the window.

Once the Ok button is activated, all the information concerning the ATFM key measures (described above) is summarized on the window. Another window appears that contains information concerning the regulations. A simple click on the name of the regulation gives the key metrics for the clicked on regulation.





CAUTION: You must not try to execute PerfAnalysis on a CASA scenario that is not already executed by CASA because PerfAnalysis reads from the output of CASA.

9.2 Input

PerfAnalysis uses the report files generated by CASA. There is a report for each regulation. The program extracts the lines of these files that are relevant to the regulation, and displays the key metric measures by regulation in the dedicated text boxes.

9.3 Output

The output of PerfAnalysis is displayed directly on two windows:

Scenario Performance metrics window contains global information about the ATFM strategy: total delay; average regulated and constrained flights; maximum delay; number of regulated and delayed flights; number of flights with delay greater than one hour; between half an hour and one hour and less than 15 minutes.

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10.0 FRED

The Flows and Regulations EDitor (FRED) tool is a graphical interface that enables the description of a regulation schema into flows description and their corresponding regulations.

Flows and Regulations EDitor FRED is developed to meet the following objectives:

- simplify the process of creating the flows,
- offer a way to describe in detail the flows (sample definition, complex definition by cutting the natural description into the logical operations between flows),
- enforce the CASA regulations on one or several created flows,
- propagate the flow attributes (identifier, time period of activation) to the attached CASA regulation,
- tailor the CASA regulations attributes (sub-periods and their applied hourly rates),
- save, in the appropriate location, a newly created scenario,
- load a previously saved scenario, and modify it as needed.

As shown above in the section SelFlow, flows and regulations are inter-dependent:

- Flows describe the upstream/downstream and the controlled zone,
- while CASA regulations enforce the ATFM measures for the flow under consideration.

10.0.1 Purpose of FRED

Flows and Regulations EDitor (FRED) is an interactive display and data generation tool that can be used to create flows and CASA regulations and to generate data files describing flows and regulations. The flows and Regulations can be modified, if necessary, and fed back into SelFlow and CASA.

The FRED tool is written in Modsim, Object-Oriented language , and uses a run-time graphics library called Simgraphics. In addition, several modules format data for input to FRED and convert the output from FRED for input into SelFlow and CASA.

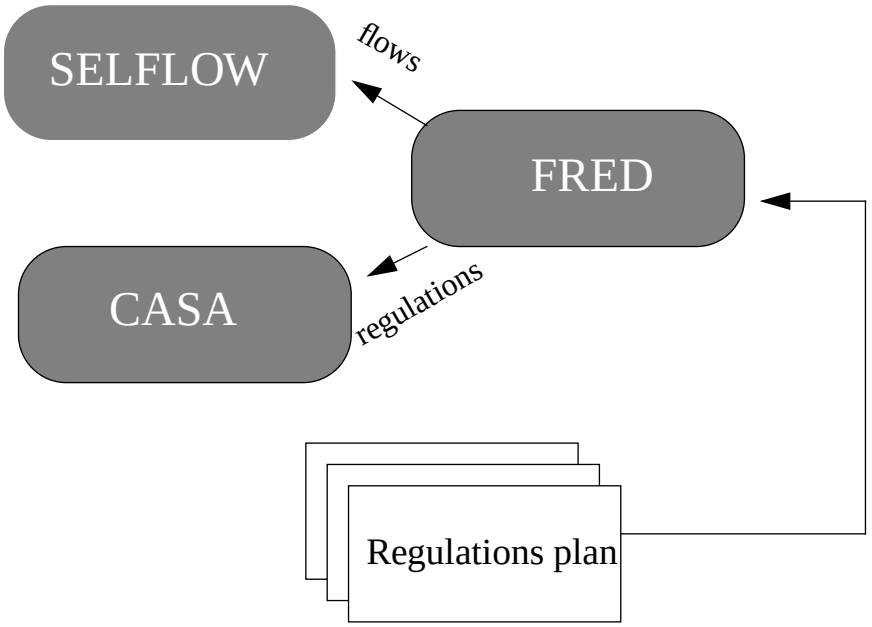


FIGURE 1. FRED Data Flow Diagram

10.1 Controls of FRED

The intention of the FRED design is to balance the three goals of simplicity, consistency, and efficiency:

- the FRED system is based on a **simple interface**,
- the FRED system is **easy to learn**, and users can get work done right away,
- when you perform a new task, you can later update it with **minimal effort**,

The FRED system uses few and simple controls to accept events or trigger an action. The controls which FRED uses are discussed below.

1. Button

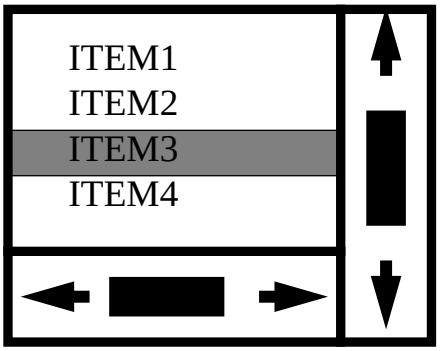
A button is used to receive a simple input event. Clicking on a button with the mouse will execute an action.

2. Text Box

A text box is used to receive a string of characters. The text box must be selected before entering text.

3. List Box

A list box is used to select an item from a list of items.



4. Radio box

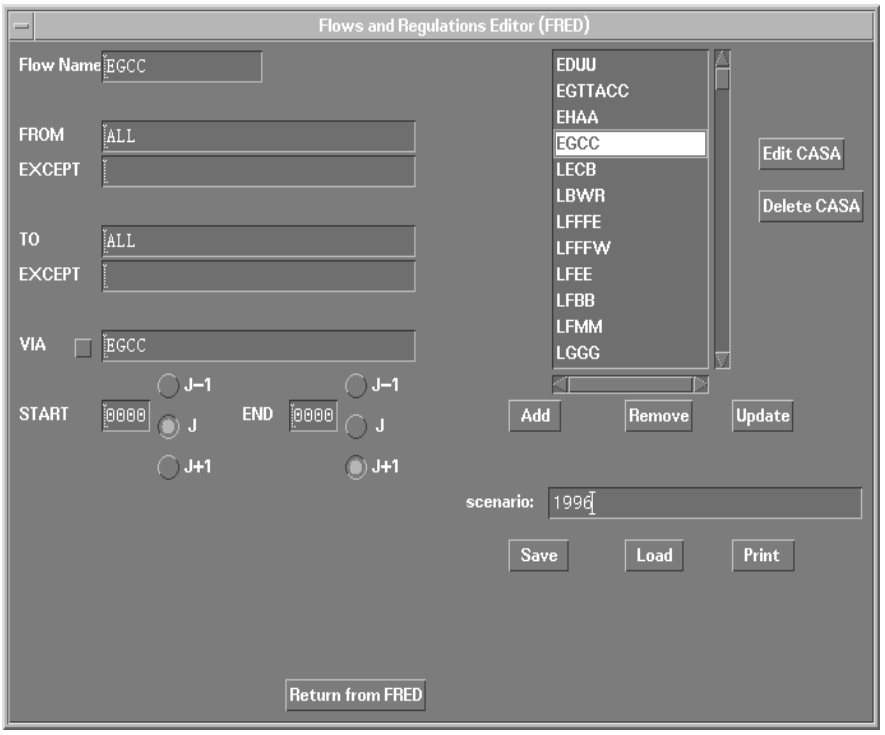
A radio box contains a list of radio buttons. Radio buttons receive YES/NO input which is mutually exclusive among the list of radio buttons.

◇ Radio Button 1
◆ Radio Button 2
◇ Radio Button 3

10.2 Starting FRED

FRED is started by executing the program “fred”. After initialisation three windows are displayed, Flows, Airports Families and Flows Operations windows are initially empty.

10.2.1 Flows Window



The Flows window holds flows being created or loaded from a previously saved scenario.

- New flows can be constructed in the create mode by entering the information in the appropriate boxes and clicking the button “Add” to insert the flow in the list of flows.
- In the select mode, the information concerning the selected flow is displayed in the corresponding box. A selected flow can be updated , removed , and CASA regulations can be assigned or cancelled from selected flows.

When all the flows and regulations are entered with FRED, the scenario can be saved, information about the scenario can be printed or displayed eg: number of flows, number of flows operations, number of Airports Families and number of CASA regulation.

10.2.2 Description of Flows window

This window allows flows objects to be edited.

1. Flow Name

A text box to specify the name of the flow.

2. FROM

A text box to specify the departure airport family.

3. EXCEPT

A text box to specify the departure airport exception from the family list, if any.

4. TO

A text box to specify the arrival airport family.

5. EXCEPT

A text box to specify the arrival airport exception from the family list, if any.

6. VIA

If checked, permits to enter the volume under consideration.

7. START

A text box to specify the start time of the flow in hours and minutes (HHMM). To specify the day of the start time, click on the Radio Box:

- J-1 : Previous day
- J : Tactical day
- J+1 : Next day

8. END

A text box to specify the end time of the flow in hours and minutes. To specify the day of the end time, click on the Radio Box:

- J-1 : Previous day
- J : Tactical day
- J+1 : Next day

10.2.3 Creating a flow

When all the above information is entered, click on “Add” button to create the flow.

10.2.4 Updating a flow

To update a flow, the following steps must be respected:

- from the list box, select the flow to be updated. All the informations concerning the flow are displayed in their correspondent widgets
- modify the informations concerning the selected flow.
- click on the button “Update”

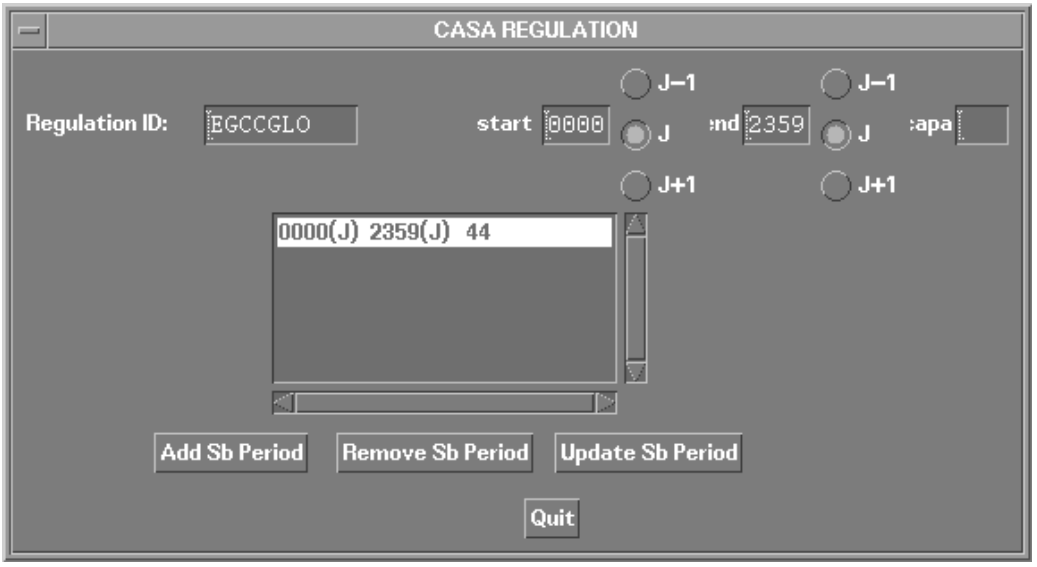
10.2.5 Remove a flow

To remove a flow, the following steps must be respected:

- from the list box, select the flow to be removed
- if a CASA regulation is attached to the flow, remove it by clicking on “Delete CASA” button
- click on “Remove” button to destroy the flow

10.2.6 Attach CASA regulation to a flow

- Before trying to attach a CASA regulation to a flow, the flow must exist in the list box and be selected. After clicking on “Edit CASA” button, the following window is displayed:



If a CASA regulation has been assigned to the flow, the window will contain all the information concerning the regulation (as it is shown in the above window), and all modifications will be automatically saved. Otherwise, the window will be empty except for the regulation ID, start time and end time that are inherited directly from the flow, plus a new button “Accept Regul”.

Each CASA regulation is identified with:

- a regulation ID which is the same as the flow name
- and a list of contiguous sub-periods with their corresponding capacities

Three modes of operations are used:

- *Adding sub-periods*

a sub-period is identified by a start time, end time and capacity. First enter the start, end time and capacity and click on “Add Sb Period” button to insert the newly created sub-periods in the list of sub-periods box.

- *Remove sub-periods*

click on the list of sub-periods box to select the period, and click on “Remove Sb Periods” to remove it. The removal of sub-period has a chain reaction because the update is transferred to the previous or next sub-period. If the sub-period is at the top of the list box, the update is transferred to the next sub-period, and in the other case, the transmission is reverse.

- *Update sub-periods*

Click on the list of sub-periods box to select the period, make your change in the corresponding boxes and save your change by clicking on “Update Sb Period” button. The update of a sub-period has, as in the case of removal, a chain reaction.

When the regulation sub-periods are created, click on “Accept Regul” button to create the regulation or on “Quit” button to cancel.

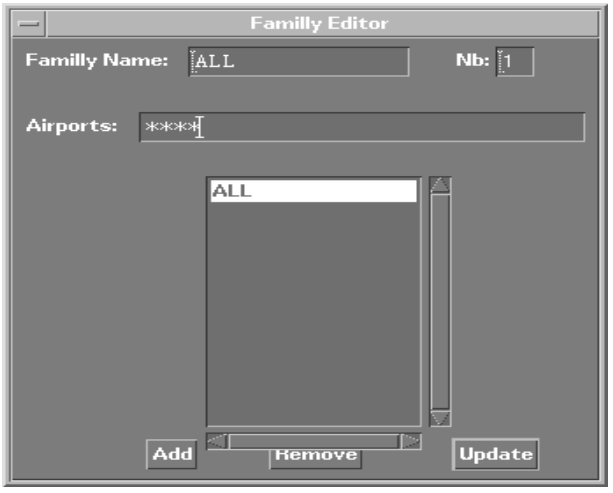
10.2.7 De-attach a CASA regulation

To remove a regulation from a flow, select the flow concerned and click on “Delete CASA” button. There is no undo button, if a regulation is removed, there is no way to get it back.

10.3 Airport Families window

The Airports Families window holds the airports families under construction or loaded from a previously saved scenario. Two modes are used creating and selecting

- New families are created by filling each box with its corresponding information, and clicking on “Add” button
- In the select mode, the information concerning the selected family is displayed in the corresponding boxes. A selected family can be updated or removed.



10.3.1 Description Of Airport Families window

This window allows the airport families to be edited.

1. Family Name

A text box to specify the name of the airport family.

2. NB

A text box to specify the number of airports belonging to this family.

3. Airports

A text box to specify the airports composing the family.

10.3.2 Creating an airport family

Once the above text boxes have been filled with corresponding information, click on “Add” Button to create the airport family.

10.3.3 Updating an airport family

To update an airport family, the following steps must be respected:

- Select first from the list box, the family to be updated. All the informations concerning the family are displayed in their correspondent boxes.
- modify the information concerning the selected family.
- click on the button “Update”.

10.3.4 Remove an airport family

To remove a family, the following steps must be respected:

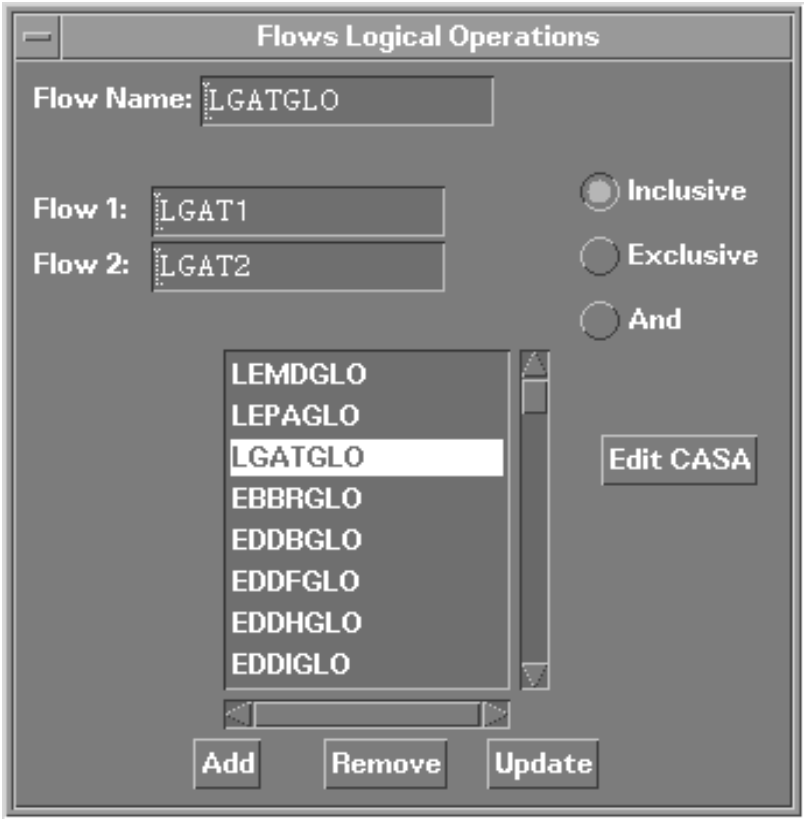
- Select first from the list box, the family to be removed.
- Be sure that this family is not part of a flow scope.
- click on “Remove” button to destroy the family.

10.4 Flows Operations window

The flows operation window holds operations on flows under construction or loaded from a previously saved scenario. Two modes of operations are used; creating and selecting:

- A flow can be created from two previously created flows and its type of operation specified. Three operations are used: Exclusive, Inclusive and And operations(see SelFlow section for explanation).

- A selected flow can be updated or removed



10.4.1 Description of the flows logical operations window

This window allows an operation on a flow to be edited

1. Flow Name

A text box to specify the name of the resultant flow.

2. Flow1

A text box to specify the name of the first flow.

3. Flow2

A text box to specify the name of the second flow.

4. Radio Box

This Radio Box allows you to specify the type of the operation between the first and second flow to produce the resultant flow (see SelFlow):

- Inclusive
- Exclusive
- And

10.4.2 Creating an operation on flows

Once all the above informations is entered, click on “Add” Button to create the operation. You must be sure that the first and second flow are well defined using the Flows window. The creation of a resultant flow is not recursive: A resultant flow cannot be used to define another resultant flow.

10.4.3 Updating an operation on flows

To update an operation, the following steps must be respected:

- from the list box select the flow to be updated. All the information concerning the flow is displayed in its corresponding boxes.
- modify the information concerning the selected flow.
- click on the button “Update”.

10.4.4 Remove an operation on flows

To remove an operation, the following steps must be respected:

- first from the list box, select the flow to be removed.
- click on “Remove” button to destroy the flow.

10.5 Save a scenario with FRED

Once all the flows, airport families, operations on flows and the CASA regulations have been created, you can save your scenario by:

- Typing the name of your scenario on the text box “scenario”.
- Clicking on the “save” Button.

If your scenario already exists, a window will be displayed to ask you if you want to overwrite or rename it.

10.6 Load a scenario with FRED

Scenarios can be loaded into FRED and edited. To do this, type the name of the scenario in the “scenario” text box and click on “load” Button.

10.7 Information about a current scenario

FRED allows you to know the number of flows, airport families, operation on flows and the attached CASA regulation. Simply, click on the “info” Button.

10.8 Exiting FRED

Selecting “Return from FRED” Button exits FRED. Any objects which have not been saved will not be lost: FRED will ask you if you want to save them or not.

11.0 ATAC (Airspace Traffic dAta Capture)

11.1 Objective

The Airspace Traffic dAta Capture, ATAC, is a data generation tool permitting the creation of crossings and traject files from the CFMU traffic.

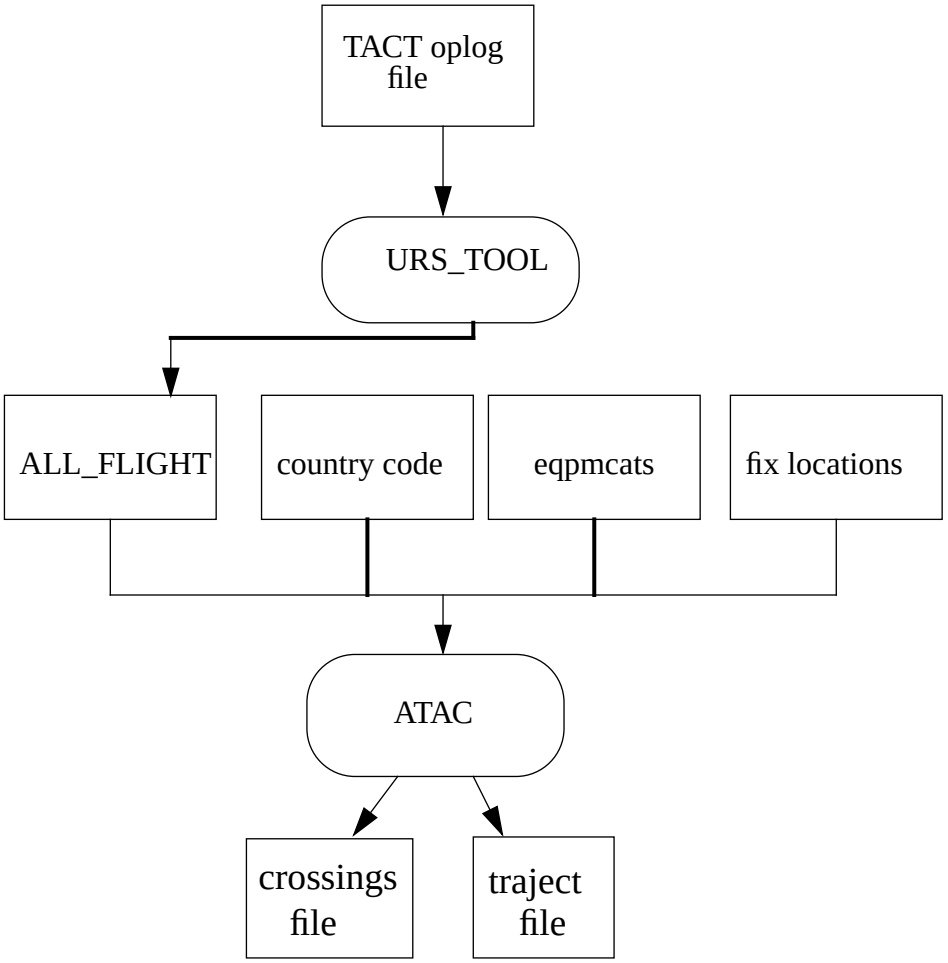


FIGURE 2. ATAC Data Flow Diagram

11.2 ATAC Module

The ATAC module is used to process the ALL_FLIGHT file for a specified operational day and produces files used by SelFlow: crossings and traject files.

11.2.1 Output files

1. crossings.<suffix>

   This file contains the scheduled flight plans of the simulated day. For each flight, a description of the en-route sectors used is given. A full description

of this file is given in the SelFlow section.

2. traject.<suffix>

   This file describes a 4 dimensional route for each flight. A full description of this file is given in the SelFlow section.

11.2.2 Input files

1. ALL_FLIGHT file

The traffic file contains the following data for each flight : departure airport, arrival airport, flight id, air carrier, aircraft type, departure date and time, flight number, flight level, followed by route (time, fix).

2. faaoag_locid_lalo.<suffix>

This file contains the fixes and airports coordinates (latitude and longitude). The CFMU traffic file records give only the fixes and airports location indicators.

3. eqpmcats

For each aircraft type this file contains the turnaround time category, the en-route time category, and the climb/descent profile.

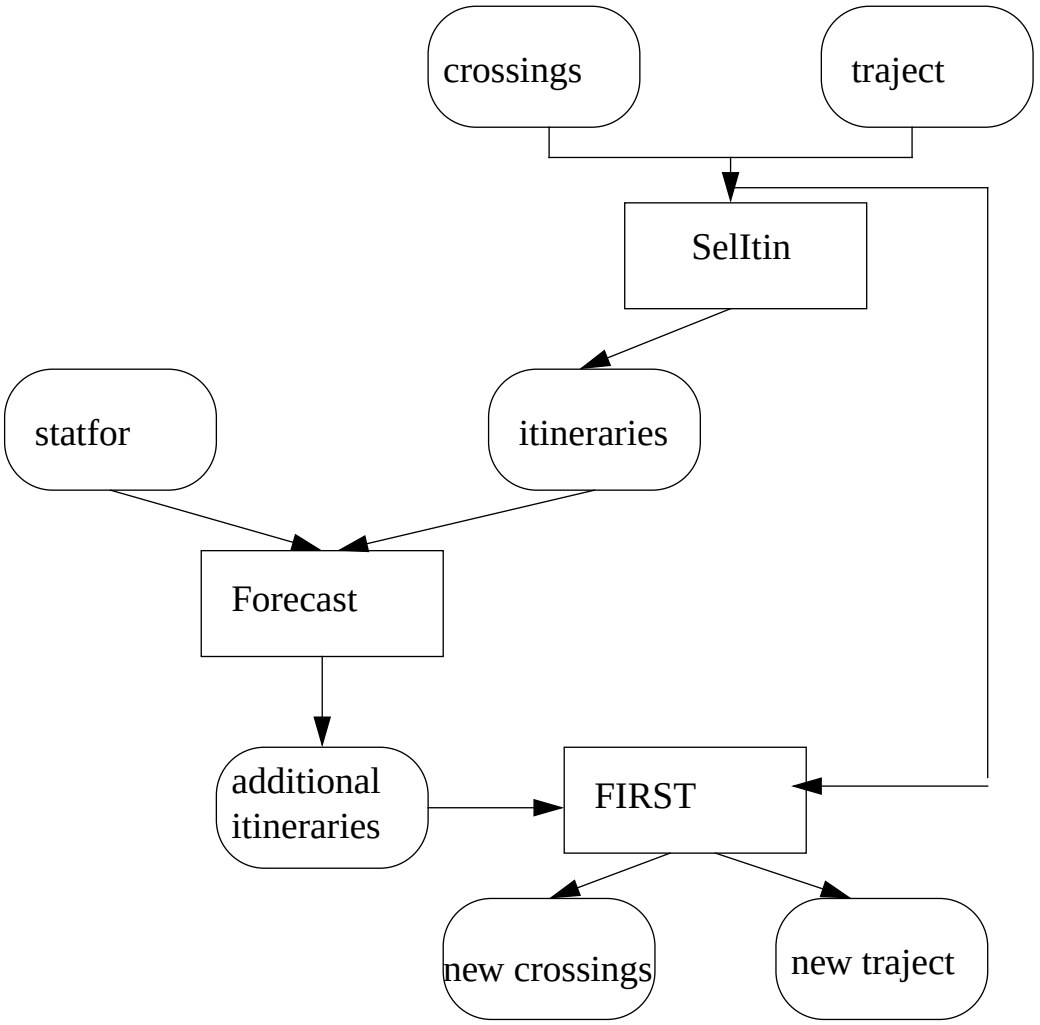
4. country code

The country code file contains abbreviations of the ICAO names. The first two characters are replaced by a single character. This file is used because sector names are coded with 6 characters, while the CFMU sector names are coded with seven characters.

12.0 Flight Increase Processor Software

The Flight Increase Processor Software (FIPS) generates additional flight demand for simulation studies. The flight demand is comprised of aircraft itineraries. An itinerary is a series of connected flight legs for a given aircraft. A flight leg is specified by a departure airport and arrival airport, an estimated departure time and an estimated arrival time. The Flight Increase Processor Software program generates aircraft itineraries according to selection criteria and assigns a four-dimensional trajectory and a list of en-route sectors to each leg. This demand reflects predicted changes for a specified future day. It is used for modeling future scenarios.

The Flight Increase Processor Software generates flights so that the hourly distribution of traffic demand is uniformly distributed over all the resources (airports, sectors, flows ...).



12.1 input files

1) Traffic

The original traffic is composed of two files: crossings file and traject file. A full description of the format of those two files is given in the section SelFlow.

2) The predicted growth file

The growth file contains the DED4 prediction about the increase of traffic. This increase concerns origin and destination pattern. The format of this file is a series of origin-destination of interest and the percentage of the flights to be generated for that pattern:

origin1;destination1;rate1

...

originN;destinationN;rateN

Each origin-destination is of the form:

airport11+airport12+ ...+airport1N-airport21-...-airport2i

The '+' sign means that the airport is part of the flow and the '-' sign means that the airport is excluded from the flow.

Example: C***+K**+PA**;EK**-EKVG;15

This line means that all departures from Canada, USA and Alaska arriving to Denmark except FAROE islands must be increased by 15%.

12.2 Ouput files

The Flight Increase Processor Software produces two output files:

- crossings file named as <crossings.orig.inc>
- and traject file anmed as <crossings.orig.inc>.

Both contain the original flights plus the newly generated ones.

12.3 Processing

The predicted growth is specified in an input file prepared by DED4 (STATFOR). The STATFOR file contains flows and their predicted growth rates. The Flight Increase Processor Software uses that file to drive the creation of new demand. The Flight Increase Processor Software consists of three separate tools:

- The Itineraries Selector (SelItin) script program extracts the aircraft itineraries from the original traffic file (crossings and traject files) and its output is an intermediate file containing the aircraft itineraries.
- The Forecast program reads statfor and the intermediate itineraries files and generates an output file containing the additional itineraries for the extra flights. For each individual flow read from statfor, the Forecast program extracts , randomly, (

rate*nb_of_flights_on_the_flow)/100 flights from the intermidiate itineraries file, and for each extracted flight a departure time is assigned randomly within the operational day.

- The Fast Insertion Routes and Sectors Tool (FIRST) uses the aircraft id to assign a four-dimensional trajectory and a list of en-route sectors to each extra flight. The times are the original times over resources plus the difference between the randomly assigned ETOT and the original ETOT.

The Flight Increase Processor Software (FIPS) is a C-shell script that controls the execution of the three separate tools. The following flow data diagram describes the way FIPS generates additional flights from the DED4 figures and the original traffic files.

12.4 Running FIPS

From the AMOC main window:

- Select the menu item "**Flight Increase Processor**" from the **Run** menu
- In the window that appears, click and enter the name of the traffic scenario to be increased.
- Enter the name of the STATFOR file containing the DED4 growth forecast.
- Click the **Ok** button to activate the FIPS or **Cancel** button to close the window.

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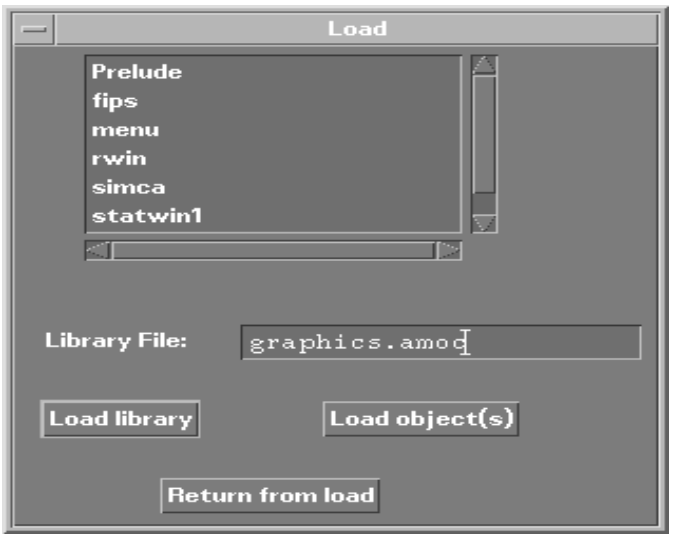
13.0 The graphical User Interface of AMOC

The graphical user interface for AMOC consists of a series of dialogue boxes and menus. From the AMOC main window, all the AMOC modules can be activated and run through their own dialogue boxes as explained in the previous sections. The AMOC GUI is coded with Simgraphics. The look and feel is of X11/Motif.

All the code of AMOC GUI is on the files DGui.mod and IGui.mod. The IGui module loads the control windows from a file called “graphics.amoc” located in the bin directory.

To edit the AMOC GUI file , you can use Simdraw. The process of editing is as follows:

- Change the current working directory to “bin” directory where the graphics.amoc file is kept.
- Type the following command: simdraw.
- From the file menu, click onto the menu item load. The following window will appear.



- On the Library Files, type graphics.amoc and click the “Load library” button. The names of all the control windows comprising AMOC will be displayed on the scrolling list. You can load any AMOC control window by clicking on the scrolling list window and afterwards on the “Load object” button.
- Once a control window is loaded, you can click onto the menu item “detail” from the “Edit” menu in order to display the internal structure of this control window.

The purpose of this section is not to give a full description of Simdraw. You can consult Simgraphics users manual to fully understand how Simdraw works.

The following outline lists the names of all control windows used by AMOC. With Simdraw you can visualise their internal structures:

menu	AMOC main window
Prelude	SelFlow dialog box
fips	FIPS dialog box
simca	CASA dialog box
rwin	PerfAnalysis regulation dialog box
statwin1	PerfAnalysis global delay dialog box
update	DeliverCtot dialog box

The graphical user interface for FRED is in a separate file located on FRED home directory. The name of this file is graphics.fred.

14.0 AMOC Advanced Features

The rest of this paper is intended for the software engineers who will maintain the AMOC Simulator. It is written for users who have basic computer skills such as managing files and using UNIX commands. All users are expected to be familiar with Modsim, Simgraphics and Simdraw. Be sure to consult documents about those languages.

14.1 AMOC Installation Instructions From a tape

The following steps outline the installation procedures of AMOC from a tape:

1. Create the AMOC “home” directory. The Unix script files that run the software provided on the tape assume that the home directory for AMOC is under “$home” directory.

2. Set the current directory to AMOC home directory and insert the tape in the tape drive. From the UNIX command line type:

tar xvf /dev/<tape device> , where <tape device> is usually rst0. If you have any doubt contact your System Administration.

This command will automatically copy the AMOC subdirectories under the AMOC home directory.

3. Under AMOC home directory, create a link to the CASA location directory. From the UNIX command line type:

ln -s <casa-location> CASA

After the AMOC files have been copied from the tape, the .cshrc file needs to be modified to contain AMOC environment settings:

setenv	AMOC	$home/AMOC
setenv	FRED	$AMOC/FRED
setenv	DATAIN	$AMOC/data/in
setenv	DATAOUT	$AMOC/data/out
setenv	casa	/net/mahler/users/casa/casa07

4. You should add the AMOC bin directory to the environment variable path. Edit your .cshrc file, and type at the end of this file the following line:

set path=($AMOC/bin $path)

5. Set the current directory to AMOC src directory and edit the mscomp.cfg file. This file is necessary to compile with Modsim. The mscomp.cfg file must contains the following lines:

1.9.13 ‘- Version of ‘mscomp’ and MODSIM II Compiler

MSEXEC> /usr/modsim1.9.13/bin ‘- MODSIM II system directory

MSLIB> /usr/modsim1.9.13/lib/modsim ‘- MODSIM II library/import directory(s)

DEF> . ‘- Definition source module directory

IMP> . ‘- Implementation source module directory
OBJ> . ‘- Object file directory

SR> ON ‘- Subrange and subscript checking
PTR> ON ‘- Pointer checking
REF> ON ‘- Reference variable checking
TB> ON ‘- Runtime error traceback
OM> OFF ‘- Generate Object Mgr info
DEBUG> OFF ‘- Generate debugger code
GRA> ON ‘- Link with graphics library
3D> OFF ‘- Link with 3D graphics library
SO> OFF ‘- Link with SimObject library
LIS> OFF ‘- Generate compilation listing
ERR> OFF ‘- Keep .err files, if any
BEEP> ON ‘- Audible prompts

14.2 AMOC Installations Instructions From a tar file

The Installation instructions from a tar file are the same as the installation instructions from a tape. The only change occur at the step 2:

1. The same instruction as before,

2. Log to the server containing AMOC home directory. Under AMOC home directory residing in this server, type the following commands:

tar cvf tarfile .
compress tarfile
exit

2-1. Ftp to the server containing the tarfile and type the following commands from the ftp prompt:

binary
get tarfile.Z
quit

2-2. From your local workstation, type the following commands:

uncompress tarfile.Z
tar xvf tarfile

3. The same instruction as before.

4. The same instruction as before.

5. The same instruction as before.

14.3 Directory Descriptions

The following outline shows the AMOC directory structure. Each directory has a README file that contains information about the directory and its contents. The information in the README files is more current than in the printed manuals. The AMOC directory structure is shown below; Note that individual files are not listed.

```
AMOC
    FRED
    CASA
    bin
    src
    com
    data
        in
        out
```

The contents of the AMOC directories and significant files are summarized below:

bin	AMOC programs and Simgraphics graphical user interface files
com	C-shell scripts including DeliverCtot, FIPS, SelItin
src	AMOC source code, except for FRED and CASA
FRED	FRED source code
CASA	virtual link to the location where CASA executables and scenarios are located
data/in	input files to SelFlow, FIPS, DeliverCtot, STAIR and ATAC
data/out	output files of SelFlow.

14.4 src directory

This directory contains the code source of all AMOC modules, except CASA and FRED codes.

14.4.1 SelFlow files

SelFlow is composed of include files (files starting with D) and the implementation files (files starting with I). The files needed to compile SelFlow are listed below:

DFlight2.mod, IFlight2.mod	They represent the definition and implementation source modules of Objects used to process flights.
DRegul3.mod, IRegul3.mod	They represent the definition and implementation source module of Objects used to process flows.
Dselflow.mod, Iselflow.mod	They represent the definition and implementation source modules of the Object “Task” responsible of triggering SelFlow. They used Objects imported from they above Definition source modules.

14.4.2 DeliverCtot files

DeliverCtot is composed of include and implementation files. The files needed to compile DeliverCtot are described below:

DdeliverCtot.mod, IdeliverCtot.mod	They represent the definition and implementation modules for the main module deliverCTOT
MdeliverCTOT.mod	This is the main module that uses the functions and structures imported from the above files

14.4.3 FIPS code files

The FIPS program is composed of a set of separate programs that perform a specific task. The following table lists the software modules that belong to FIPS and briefly describes their include and implementation files. A more detailed overview of FIPS, including its components, is given in the section dedicated to FIPS. Only the logical files used by FIPS are described below. These files contain the definition and implementation of structures and functions used to generate additional flights from the DED4 prediction file:

Dfirst.mod, Ifirst.mod	They represent the definition and implementation modules for the main module FIRST
MFIRST.mod	This is the main module that uses the functions and structures imported from the above files
forecast.c	This is the code for forecast program

14.4.4 PerfAnalysis code

The Performance analysis code is encompassed in the module DGui.mod and IGui.mod under the object ScDelayDialogObj.

14.5 CASA src

There is a virtual link to the location where CASA executable files and scenarios are located. This link must be updated each time the CASA host server changes.

14.6 FRED src

The FRED code is located on the FRED directory under the AMOC directory. The contents of this directory are described below:

DFRE.mod , IFRE.mod	They represent the definition and implemenatation module of FRED
Mfred.mod	This is the main module
graphics.fred	This is the GUI of fred. You can edit it with Simdraw utility
DOS.mod, IOS.mod, OS.c	These are the interface to C routines

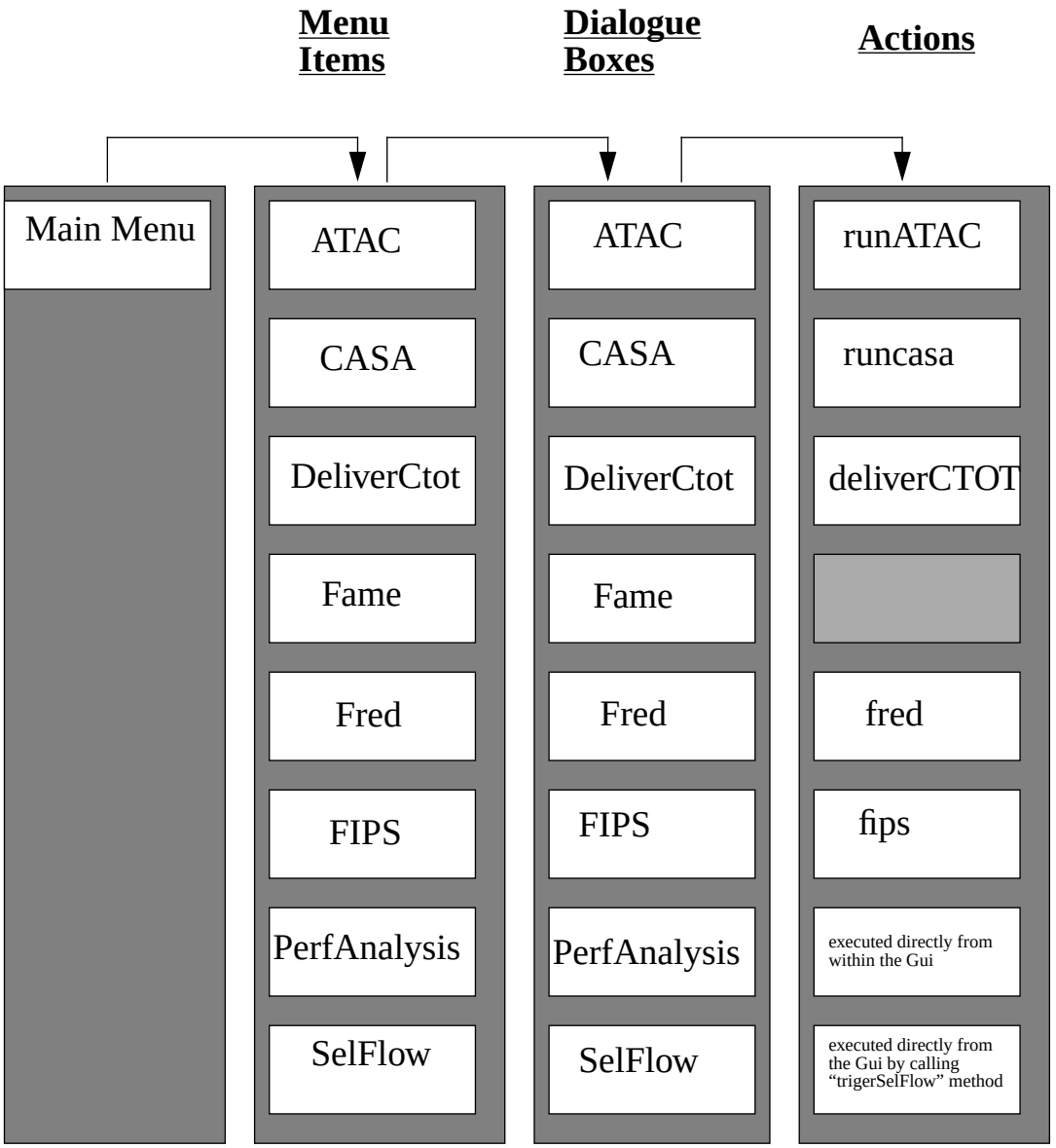
14.7 com directory

The com directory contains script used to start DeliverCtot, FIPS and CASA.

14.8 Graphical User Interface Logical Structure

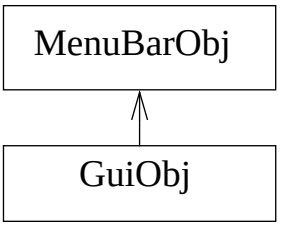
The graphical user interface for AMOC consists of a series of dialogue boxes and menus. From the AMOC main window, all the AMOC modules can be activated and run through their own dialogue boxes as explained in the previous sections. The AMOC GUI is coded with Simgraphics. The look and feel is of X11/Motif.

The following diagramoutlines the functional and hierarchical organisation of the menus:



14.8.1 Main Menu

The AMOC main menu is a menu-driven software tool that lets you starts any AMOC module. The AMOC main menu called “GuiObj” is an object inherited from Simgraphics Object “MenuBarObj”.



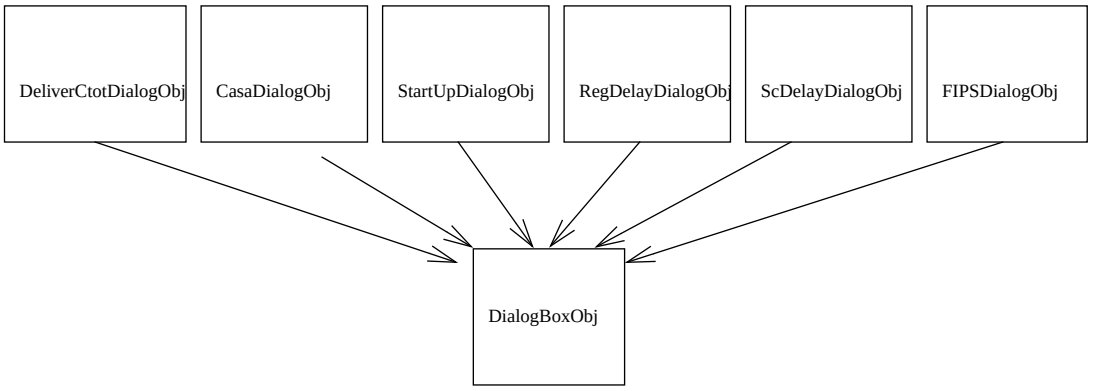
14.8.2 Menu Items

The AMOC main menu lets you starts any AMOC module by clicking on the menu items corresponding to the module to be run. The GuiObj reads an ASCII file called “graphics.amoc” from which it loads its menu.

Each menu item activates an object inherited from Simgraphics “DialogBoxObj”. Thus, the GuiObj uses the implementation of the dialogue boxes objects described below.

14.8.3 Dialog Boxes

Each click on a menu item displays a dialog box from which you can enter the name of input files needed to start the execution of the module. Each dialogue Box is an object inherited from Simgraphics object “DialogBoxObj”.

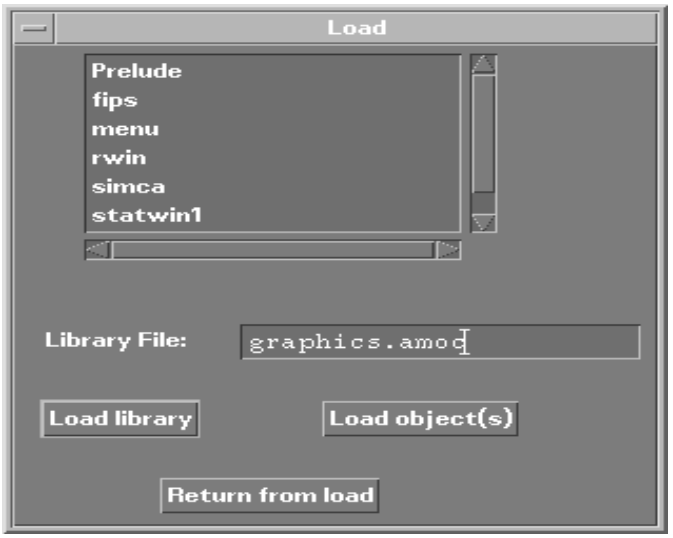


Each dialogue Box object reads the “graphics.amoc” file from which it loads the structure describing its GUI internal presentation.

To edit the AMOC dialogue boxes internal presentation , you can use Simdraw. The process of editing is as follows:

- Change the current working directory to “bin” directory where the graphics.amoc file is kept
- Type the following command: simdraw

- From the file menu, click onto the menu item load. This window will appear



- On the Library Files, type graphics.amoc and click onto “Load library” button. The names of all the dialogue boxes internal presentation composing AMOC will be displayed on the scrolling list. You can load any AMOC control window by clicking on the scrolling list window and afterwards on the “Load object” button.
- Once a control window is loaded, you can click onto the menu item “detail” from the “Edit” menu in order to display the internal structure of this control window.

You can consult Simgraphics users manul to understand how Simdraw works.

The following list outlines the name of each control window used by AMOC; with Simdraw you can visualise their internal structures:

menu	AMOC main window (GuiObj)
Prelude	SelFlow dialog box (StartUpDialogOj)
fips	FIPS dialog box (FIPSDialogObj)
simca	CASA dialog box (CasaDialogObj)
rwin	PerfAnalysis regulation dialog box (RegDelayDialogObj,)
statwin1	PerfAnalysis global delay dialog box (scDelayDialogObj)
update	DeliverCtot dialog box (DeliverCtotDialogObj)

14.8.4 Actions

Each dialogue box executes a C-shell script, an executable code through a system call, or directly calls a function from within the GUI code. The following outlines the action taken when validating a dialog box:

A. runcasa

runcasa is a C-shell script that takes two arguments:

runcasa <casa database server> <casa scenario>

Where <casa database server> is the server containing CASA database and <casa scenario> is the directory (without pathname) containing CASA regulations files, traffic volume file and CASA services call file.

B. DeliverCtot

deliverCtot is a C-shell script. It takes three arguments:

deliverCtot <traffic extension> <casa scenario> <casa server>

Where <traffic extension> identifies the crossings and traject extensions, <casa scenario> is the directory (without pathname) containing CASA regulations files, traffic volume file and CASA services call file, and <casa server> is the CASA host server

```
#!/bin/sh

 if [ ! -f /net/$3/users/casa/casa07/$2/temp ] ; then

echo “scenario “ $1 “ does no exist or not run yet”

exit 2;

fi

temp=/net/$3/users/casa/casa07/$2/temp

 egrep “(UPDATE_CTOT)” $temp | awk ‘{print $5 “ “ $6 “ “ $8}’ > ../data/in/temp

../bin/deliverCTOT $1 temp

rm ../data/in/temp
```

C. FRED

fred is an executable program located in the FRED home directory. This program is coded using Modsim and Simgraphics library. To compile FRED, you must follow these steps:

1. Set the current directory to FRED home directory. From the UNIX command, tape the following command:

cd $FRED

2. From the FRED home directory, tape the following command:

mscomp fred

The graphical user interface for FRED is in a separate file located on FRED directory. The name of this file is graphics.fred.

D. FIPS

The fips, located in AMOC com directory, is a Cshell script used to generate additional flights data from an original traffic file. It takes two arguments:

fips <traffic extension> <statfor>

Where <traffic extension> identifies the crossings and traject extensions, <statfor> is the file containing the DED4 prediction growth. The <statfor> file is specified by name without the whole pathname.

E. PerfAnalysis

The PerfAnalysis module is executed from within the GUI without passing by a system call. The full code of PerfAnalysis module is encompassed in the object “RegDelay-DialogObj” and “ScDelayDialogObj”.

F. SelFlow

The SelFlow module is executed from within the GUI without passing by a system call. The full code of SelFlow module is encompassed in the object “StartUpDialogObj”. The method that starts SelFlow is “triggerSelFlow”.

15.0 AMOC as a host test bed for CARAT

The main objective of the CFMU is to make the best use of the available capacity without any increase to controller workload. Several alternatives can be used to cope with the problem:

- One alternative is by providing departure slots with regard to the companies schedules. This alternative is an effective but costly means of maintaining traffic flows within limits, causing considerable disruptions in airline schedules and the appearance of overload peaks in the en-route sectors.
- The other solution is the dynamic rerouting in response to identified imbalances between demand and capacity. Technically, the solution implies the computation of which flights are to be rerouted in order to minimize a cost function, while satisfying the constraint not to exceed sector capacities. A key abstraction in this problem is the definition of what is the cost. Actually, there are several different kinds of cost. Anything that affects the airlines schedules and the complexity of managing the airspace must be measured, and so we must include the length of the new itineraries, pilots manoeuvres (zigzag routes) , the controllers workload (several entrance/exit into the same sectors) and so on.

The **C**omputer **A**ided **R**oute **A**llocation **T**ools **CARAT** is an optimisation rerouting tool which is under development at EUROCONTROL Experimental Centre. Its responsibilty is to reduce the ATC overload by modifying the itineraries of some flights without introducing any extra delays for those flights. CARAT will be placed upstream/downstream of the Computer Aided Slot Allocation CASA.

For the testing and validation of CARAT algorithm, a test bed environment is needed. Many possibilities are open:

Build an interface with TACT System. This is the best solution for the test and the validation of the CARAT algorithm because CARAT will be part of TACT and TACT already contains existing services needed by CARAT. But it's a costly option because it involves the acquisition of a new full version of TACT with source code, support from TACT team and mastering of the TACT code. According to TACT project leader, it takes more than 6 months to master TACT code and configuration. This alternative will impose severe limitations to CARAT design and introduce delay in the CARAT delivery.

Plug and Play Model. For the time being, the above solution is not realisable in the immediat short term at the EEC. We are unable to master a complex system as TACT, it's better to deal instead with a more generalised model. This option has a lot of advantages:

- It gives maximum freedom for testing CARAT without being dependent on a specific environment,
- It simplifies the design and integration process of CARAT because it separates the essential behaviour of CARAT from the test bed and concentrates the intention, in the integration process, only on the outside view of CARAT. This behaviour/integration separation will limit the side effects inherent to the interface implementation.

From the above observation, CARAT design should be achieved through an independent architecture from the host test bed environment. The conceptual boundaries separation facilitates the interaction between CARAT and any eligible model, through a well-defined collection of services and eliminates the possibility of breaking the internal implementation of CARAT each time the host changes. If we stick to a conceptual design independent from any host, we're going to gain more freedom and flexibility in testing and experimenting with CARAT, and we can even power up other simulators available at the EEC with the rerouting facility by applying the 'plug and play' mechanism.

Lots of hosts, at the EUROCONTROL Experimental Centre, are candidates for CARAT testing, but at the time being we are interested only in AMOC. This choice is dictated by the following reasons:

- AMOC is primarily based on CASA as one of its more important components (CARAT will be placed upstream/downstream of CASA),
- AMOC has a similar behaviour as TACOT,
- There is already a connection from AMOC to TACOT (mode simca).
- AMOC is a reliable tool. It was used intensively for the CFMU studies before installing TACOT at the EEC, and now it's used successfully for FAP study.

15.1 Why restructuring AMOC

As outlined earlier, we can conclude that AMOC is a good candidate for CARAT testing. However, this integration require enhancement and flexibility in the way AMOC works. The architecture of AMOC should be adjusted to allow an effective and fast communication between its components. For the moment, all AMOC components communicate through files.

An efficient application must: minimize the number of steps required to perform an operation; must hide the details of processing from the user, keeping controls out of the way until they are required; then displaying controls based on actions users take that suggest a need for additional information. As an example, AMOC might automatically detect overloaded sectors and take actions without any human intervention unless it is suggested otherwise, or propose the best sectors configuration adaptable to a defined traffic pattern. At the time being, the communication between all AMOC components is simpl . This is not to say that such system is crude and inelegant, but as AMOC gains notoriety through successful studies, we can afford to look for new alternatives to make it work properly and efficiently.

15.2 Distributing AMOC

A far better way to optimize AMOC would be to completely restructure its components through a set of fine-grained co-operating processes. Each has a well-defined behaviour and a limited action in time and space. As Dijkstra suggests, "The technique of mastering complexity has been known since ancient times: *divide et impera* (divide and rule)". In this manner, we augment our knowledge about the system interactions and we can easily study each process in isolation. The approach adopted is to run all AMOC processes on different machines in a networked environment, or in different address spaces, or indeed, within the same address space. All the distributed computing

supports all the outline mechanisms allowing the co-location of all the processes in the same address, or keep them separate. AMOC must be able to take the adequate action when the network is down or the dedicated machines are occupied, by switching to a local execution. In practical terms, this means that in the scarcity of the network resources, a collocation of all AMOC processes in the same machine must be adopted automatically.

15.3 AMOC processes

The following list contains the complete set of AMOC processes and the identified relationship between them:

- The profiler process takes a route (set of consecutive fixes), a flight category and a set of vertical restrictions and produces a 4D trajectory.
- The crossings process takes a 4D trajectory, a set of elementary sectors and determines the en-route sectors and their times of piercing. A traffic pattern will be produced and stored in a shared memory.
- The count process will read from the shared memory and produces hourly traffic for a specified sectors configuration. Each time a sector exceedss its capacity, count will send a message to SelFlow notifying it of the overloaded sector, the corresponding period and the capacity.
- Upon receiving the notification, SelFlow will create a regulation to protect the sector and extract the associated traffic. The traffic will be stored in a bucket for later transfer to CASA.
- When all the overloaded sectors are identified and notified to SelFlow, count will send an ‘end trame’ to notify SelFlow that it can activate CASA. At that time, SelFlow will create a CASA execution environment.
- Once CASA has finished processing slots allocation, Update_Ctot will inject the new Ctot into the shared memory.

The process loops untill all the sector capacities are respected.

The rest of this section will deal only with the way CARAT and AMOC could be interfaced and the new functions needed.

15.4 The approach proposed

The basic principle behind CARAT algorithm is to propose k-short path for each selectable flight crossing an identified congested area. Simply stated, the purpose of CARAT is to efficiently and with minimal cost reroute flights from the overloaded sectors. There are three important parts to these requirements:

- Identification of congested area
- Input of selected flights
- Search in space and time of the alternative routes

Because of the complexity of the problem to solve and the amount of time calculation it requires, we should separate the k-short path search algorithm from the mechanism of identifying the bottlenecks and calculating the flights profiles.

15.5 Roles and Responsibilities

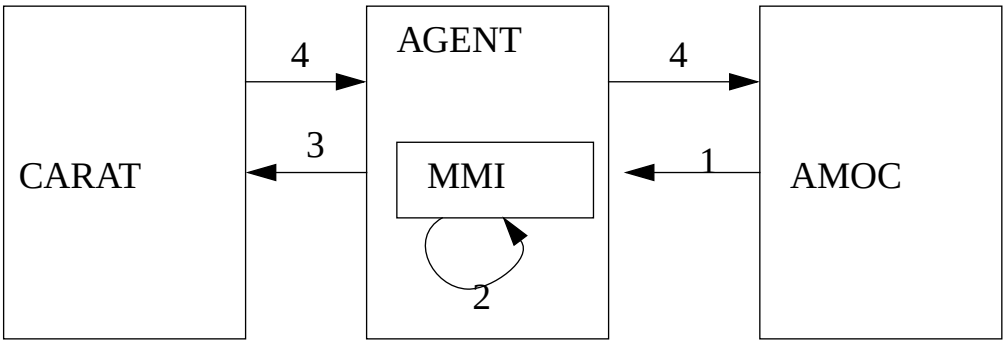
AMOC responsibility The role of AMOC is to provide CARAT with the necessary services in order to work correctly. These services will encompass (a) the identification of congested area by tracking the hourly distribution of the traffic in all the sectors, (b) sending to CARAT the set of flights subject to rerouting, and (c) computation of the profile and sectors piercing, individually, of the itinerary of each flight submitted by CARAT.

CARAT responsibility The role of CARAT is the search in space of new flight itineraries that will minimise the overload. CARAT will request from AMOC the calculation of the profile and sectors crossing for each involved flight.

Synchronisation Agent There is a need for an agent responsible for synchronizing the messages passing between AMOC and CARAT. We have found that two kinds of messages are of particular interest in this field:

- Display of the congested area in a form to be defined later and the ability to select , from the congested area, those flights subject to rerouting and to send them to CARAT
- Display and validation of the new routes.

The implementation of such agent could be provided as a process-to-process message transfer files configuration or both through switch command.



(1) AMOC sends all the congested areas (flights with routes and list of en-route sectors) via the software bus to the MMI

(2) The MMI allows the user to display those congested areas in the shape of icons. The icon that represents each congested area may be selected. When clicked on, the icon displays all the flights related to the area and allows the user to select some of them for rerouting.

(3) CARAT will search for new itineraries for the selected flights,

(4) and send them to AMOC in a ‘what-if’ reque

16.0 ATFM Simulator capability

16.1 What do we offer?

Scientific research and engineering development, related to the ATFM, are relying increasingly on computational simulation to augment theoretical analysis, experimentation, and testing. Many of ATC and ATFM problems are far too complex to yield to mathematical analyses. Simulations play an even greater role in providing solutions to our most challenging problems. In this context. The ATFM simulator is developed to simulate a wide range of ATC and ATFM functions, which can be applied to carry out studies:

- The simulator can be used to identify the bottlenecks in a defined airspace organisation.
- The simulator can be used to carry out a deep analysis of the CFMU operations (strategic and pre-tactical phases) and evaluate proposed solutions.
- The simulator can be used to evaluate new alternative ATFM strategies and evaluate new approaches to adopt in case of TACT/CASA System failure (Preparation of contingency plans).
- The simulator can be used to validate the application of optimisation techniques (operations research, constraint-based approach) to reduce system-wide delays and congestion.

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GLOSSARY

AO	Aircraft Operator
AMOC	ATFM Modelling Capability
ARC	CFMU Archive system
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
CASA	Computer Assisted Slot Allocation
CFMU	Central Flow Management Unit
COFEE	Checked Operational data FEEder
CTOT	Calculated Take-Off Time
ECAC	European Civil Aviation Conference
EEC	EUROCONTROL Experimental Centre
ENV	CFMU Environment system
EOBT	Estimated Off Block Time
ETO	Estimated Time Over
ETOT	Estimated Take-Off Time
FAA	Federal Aviation Administration
FAP	Future ATM Profile
FDR	Flow Data Research
FIPS	Flight Increase Processor Software
FPL	Flight Plan
FRED	Flow and Regulation EDitor
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
IFPS	Integrated Flight Plan System
IFR	Instrument Flight Rules
IPEAS	Indicators for Performance of the European ATM System
NASPAC	National Airspace Syst Performance Analysis Capability
PFD	Planned Flight Data
RPL	Repetitive Flight Plan
SAM	Slot Allocation Message
SIP	Slot Improvement Proposal message
SIT	Slot Issue Time
TACT	CFMU Tactical system

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SPECIAL TERMS

Airborne Delay: The delay incurred by in-flight traffic (holding patterns, speed reduction ...).

Airport Service Time: The minimum separation in time between two flights.

Combined flights: Flights subject to several regulations.

Congested area: Any volume where the traffic demand exceeds the ATC capacity.

Constraint Programming: An approach that uses operational research and artificial intelligence to resolve complex combinatorial problems.

Effective delay: The difference between an aircraft scheduled arrival time and its actual arrival time in the simulation.

Ground Delay: The delay obtained by the process of Slot Allocation Procedures.

Flow: A set of flights coming from a common zone of departure and/or going to a common zone of destination and/or proceeding via a common airspace volume.

Host Z data: Aircraft plan and track updates messages sent by the en-route centre computers to the Central Flow Control Facility (USA).

Itinerary: A series of connected flight legs for a given aircraft (NASPAC).

Leg: Individual flight specified by its departure airport and arrival airports, an estimated departure time and an estimated arrival time.

Optimisation Model: Mathematical representation of a system; along with a method, or algorithm for generating strategies that adhere to certain constraints and a method for evaluating those strategies in terms of one or more criterion called objective functions.

Regulation: A perfect adaptation between traffic demand and ATC capacity.

Slot Allocation Procedures: The slot allocation procedures are ATFM measures aimed at fully utilising available ATC capacity by issuing time slots on an individual basis for each flight concerned.

Stochastic: Arising from chance; involving probability.

Technical Delay: Delay absorbed by aircraft while waiting for ATC resources. For example, waiting to use a departure runway accumulates technical delay.

Throughput: The number of aircraft entries into a controlled zone during a given period.

Throughput Deviation: The difference between the observed throughput and the declared capacity.