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LINK 2000+ Business Case Development Simulation (L2KBC) Final Report

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Abstract:

This report describes an experiment to gather data in support of the LINK 2000+ Business case associated with the introduction of datalink communication. Traffic samples representing 4 proportions of datalink-equipped aircraft and 3 levels of traffic load were used. The experiment was conducted using a simulation of a portion of airspace of Reims ACC, Paris ACC and Maastricht UAC.

The concept was well received. There was a general feeling that datalink was of benefit to the controller although it should be supported by improvements to the underlying HMI and to the operational concept of operations. Some general issues about responsibility and task delegation between Planner and Executive were raised.

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1. Introduction

The purpose of this document is to describe the conduct, measurements and analysis that was performed in support of the LINK2000+ simulation. This simulation, which was in support of the Business Case development associated with the use of datalink communication was referred to as **L2KBC**. The simulation was conducted at the EEC between 15 September 1999 and 28 September 1999 inclusive.

The L2KBC experiment was based upon a comparative study of a baseline system and an advanced system employing datalink communication. The baseline system was one that has been derived from work carried out in the series of EATCHIP experiments. This baseline system represents a strip-less ATC system, using colour, direct interaction with the radar label and System Supported Co-ordination (SYSCO). Within the baseline, the transmission of control instructions was performed using traditional r/t methods.

The advanced system also used the EATCHIP Human Machine Interface (HMI) but additionally provided the controller with the option of using datalink technology (CPDLC) for the transmission of non-time critical messages to those aircraft with the necessary equipment and with downlinked aircraft parameters.

The use of a common HMI between the baseline and advanced systems was to enable the effect on controller workload resulting specifically from the use of CPDLC to be quantified. The simulation ensured that the demand (number of aircraft entering the measured sector) and the datalink equipage (percentage of these aircraft with a CPDLC capability) were varied in a controlled manner, as described in Section 5.

The L2KBC simulation was designed as a “low-risk” experiment in that it used much of the system architecture associated with the series of EATCHIP 3 experiments and most notably the EOLIA platform. In contrast to the EOLIA/EATCHP 3 data link simulation, described fully in Reference 1, the L2KBC simulation employed a modified airspace configuration and defined its own traffic samples.

The series of EATCHIP experiments have been designed with a common philosophy, different to most large scale real-time simulations, in that each study is designed to be *‘just detailed enough*’ to answer the questions posed. Furthermore, within the EATCHIP series of experiments there is :

- a high degree of continuity between successive studies, e.g. airspace etc. is changed only for specific reasons concerned with the operational and technical issues being examined,

- a high degree of dependency between the studies. The purposes and objectives of each study are open to reflect the results and experiences of the previous studies and sources of variance are kept to a minimum.

The L2KBC simulation was required to provide a number of data sets suitable for exploitation in a traditional cost/benefit analysis. However, the simulation did also generate a fair amount of useful feed-back regarding the datalink concept and its integration with the underlying HMI. The aim of this report is to present these findings and in so doing to be a self-contained complement to the cost/benefit analysis.

2. Simulation Objectives

The L2KBC simulation was conceived in order to assist with the cost/benefit analysis associated with the datalink concept within the LINK 2000+ project. The primary aim of the simulation was to therefore provide objective data pertaining to the following :

1. *The effect of CPDLC operations on controller workload.(The availability of CPDLC was supplemented by the ADS function of CAP (Controller Access Parameters) which provides the controller with downlinked heading, speed and vertical rate information.)*

2. *The effect of CPDLC operations on the Level of Service provided to airspace users.*

3. *The effect of CPDLC operations on the participating controllers perception of safety.*

In addition, the simulation was required to provide further subjective information regarding the use of datalink and the requirements of the underlying HMI as part of the continuing EATCHIP development process.

A number of operational working practices were defined before the experiment, namely :

1. Open dialogues will be closed before transfer of flights.

2. The reflex action for the Controller should be immediate “revert-to-voice” to clarify any non-nominal situations or to ensure aircraft compliance in time-critical situations.

3. The participating “measured” controllers should define a team working methodology i.e. task allocation between the radar and planning controller to ensure that the available technology is used to maximum benefit

Following the last EOLIA/EATCHIP 3 experiment, the importance of the datalink transmission delay was highlighted as was the necessity for a high proportion of successful dialogues. It was anticipated that the simulation would provide a realistic platform for the assessment of the objectives providing that an acceptable delay and success rate were maintained.

When using CPDLC, it is expected, that a reduction in r/t load be observed. This should permit the devotion of this “gain time” to other tasks, thereby potentially increasing the sector capacity and level of service provided to the airspace user.

The availability of CAP data (track, speed and vertical rate) to the controller is also expected to contribute to the reduction in r/t load.

3. Simulation Description

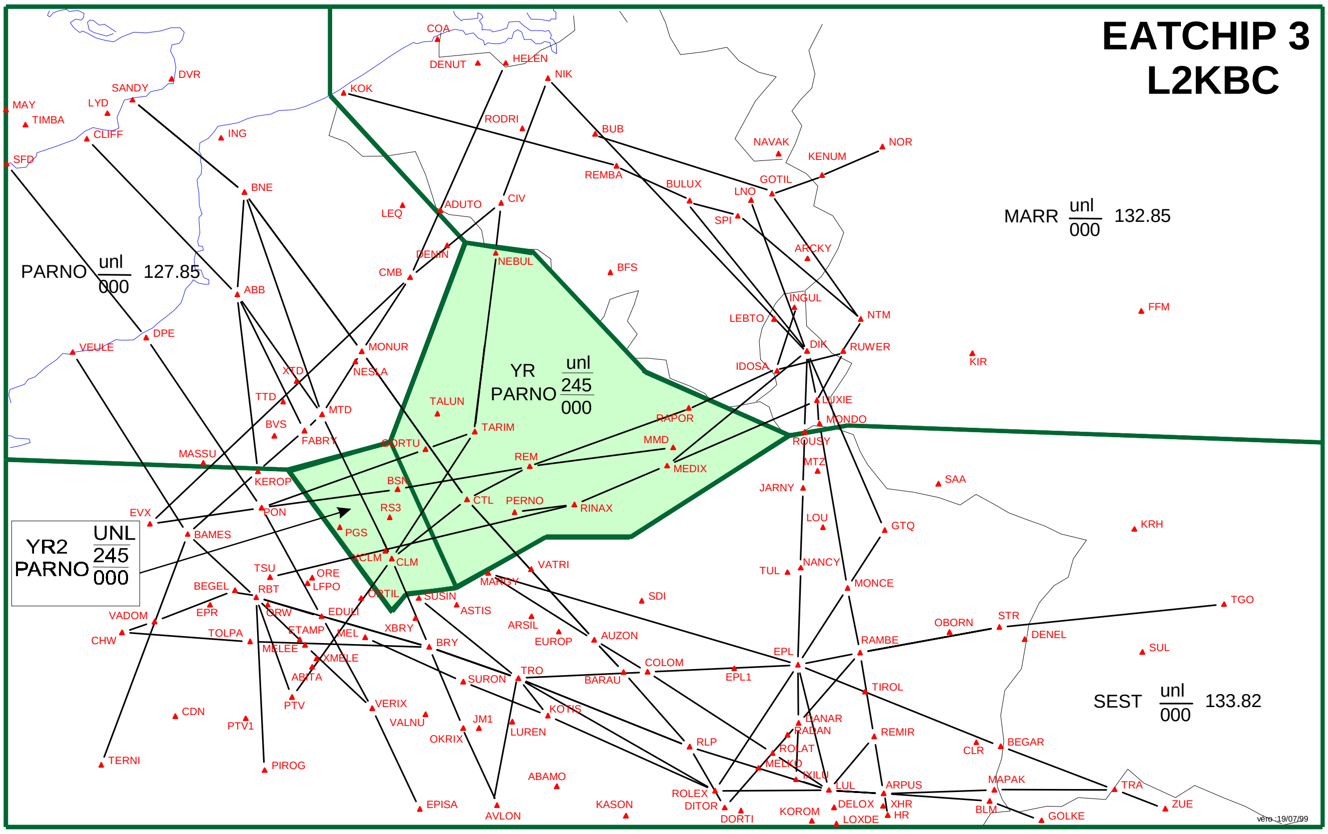
3.1 Simulated Airspace

The L2KBC simulation area comprised adapted sectors from Reims, Paris and Maastricht ACCs. A single “measured” sector (comprising planning and tactical positions) corresponding to the Reims sector YR (FL245 to UNL) was employed.

The continuity of control with the adjacent control units was assured by three “feed” sectors. The table below illustrates the sector configuration used throughout the simulation:

Sector Name	Status	Vertical limits	Frequency
Reims sector YR	Measured	245-UNL	135.5
Paris	Feed	000-UNL	127.85
Maastricht	Feed	000-UNL	132.85
SEST	Feed	000-UNL	133.82

For the measured sector YR, the ATC working procedures corresponded to those applicable for the given route structure being simulated and were in accordance with the appropriate Letters of Agreement. The control actions of the feed sectors were kept to a minimum, although updating of the data block and response to co-ordination requests was required. The airspace configuration is shown below :

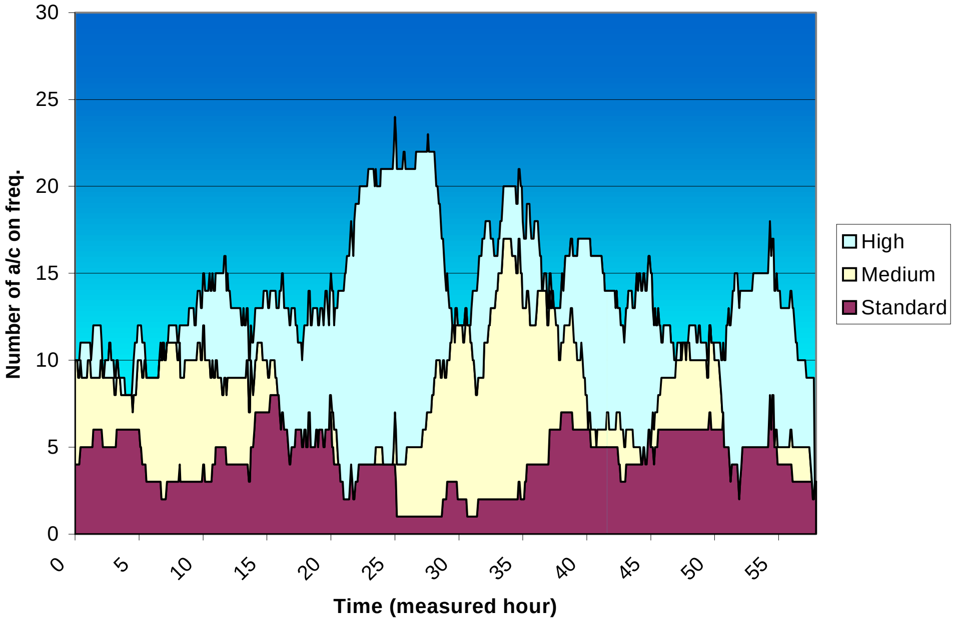


3.2 TRAFFIC SAMPLES

The traffic samples were created at the EEC based on recordings of flight plan information available from the CFMU for the 24 hour period of 7 August 1998. In order to understand the evolution of controller workload with traffic volume, it was necessary to construct a number of different samples ranging from “relatively easy” to “difficult”. Each traffic volume was constructed from a different period within the 24 hour time-slice of available data.

For each traffic sample volume, four different datalink percentages were assessed, corresponding to 0% (baseline), 50%, 75% and 100%. Military and VFR traffic were not included in the assessment.

The traffic samples were validated for their realism and suitability for the experiment by the EEC data preparation cell and operational controllers from Reims ACC. This initial validation took place at Reims ACC in August 1999 and was complemented by more in-depth validation at the EEC using standard preparation and analysis tools in early September 1999. The complete validation exercise ensured that the volumes would expose the controllers to the different workload “régimes” required by the experiment and ensure that the aircraft profiles were consistent with those experienced within the sector being studied. The following figure shows the distribution of aircraft on the sector YR frequency during the measured hour for each of the three traffic volumes.



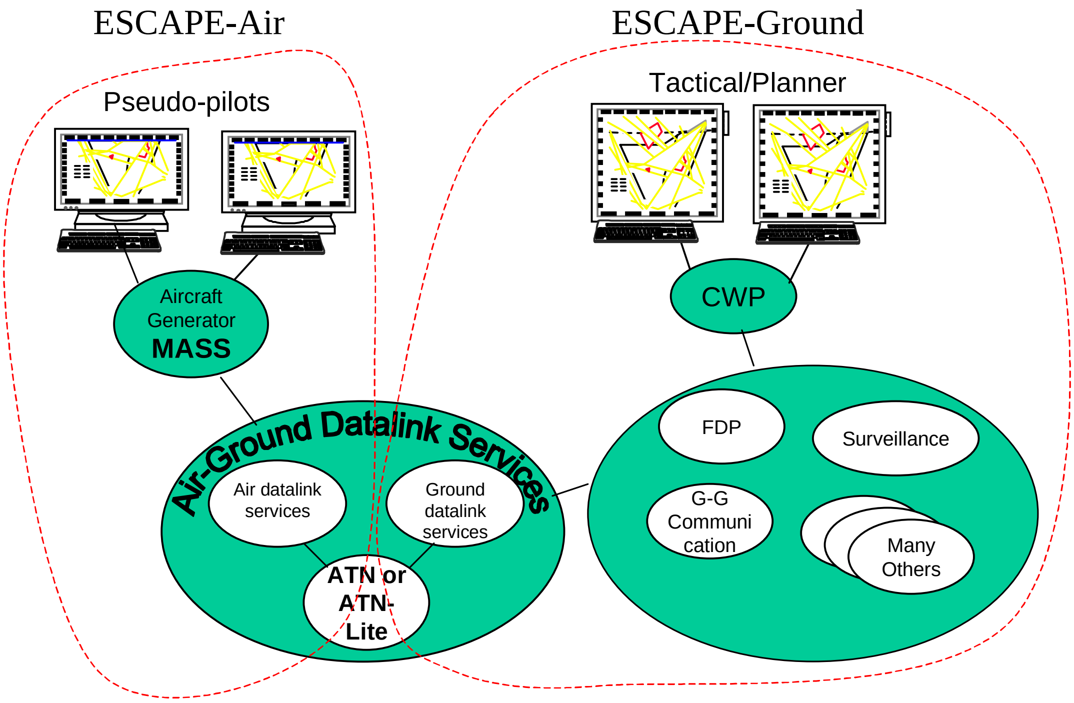
In terms of hourly flow rates, i.e. number of sector entrants, the traffic samples had the following characteristics :

Traffic sample	Hourly flow rate
Standard	**42**
Medium	**64**
High	**81**

4. Simulator Components

4.1 Datalink

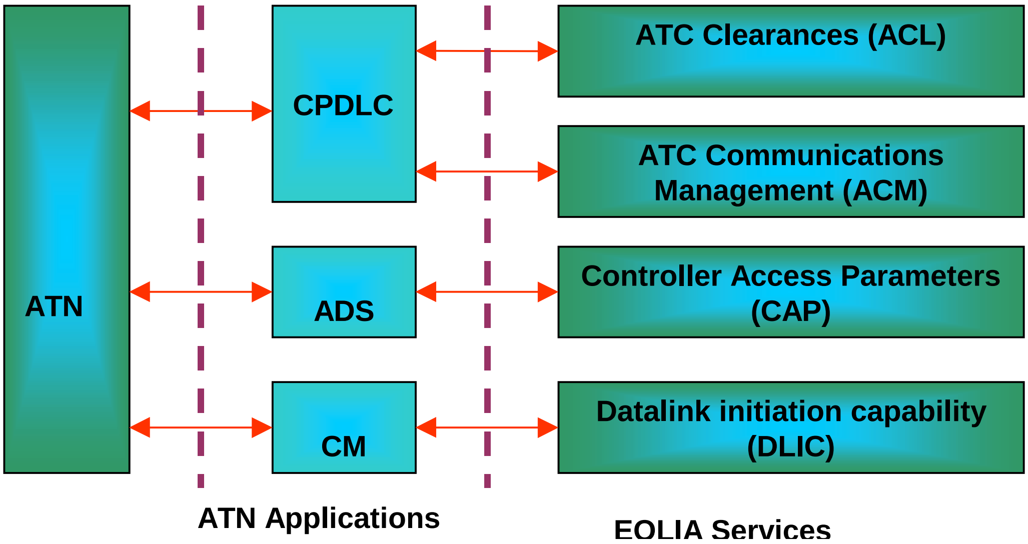
The ESCAPE real time simulator comprises two parts, the air system and the ground system. Within L2KBC, these two systems communicated via an ATN emulation called ATN-Lite



The ESCAPE ground system consists of the Controller Working Position (CWP), and additional components performing the functions of flight data processing, ground-ground co-ordination and surveillance. It also includes the ground part of the datalink services and the interface to the ATN.

The ESCAPE air system is comprised of the pseudo-pilot positions for the aircraft generator (MASS), and the air part of the datalink services. A more detailed description of the implementation of the ATN Lite system can also be found in Reference 1.

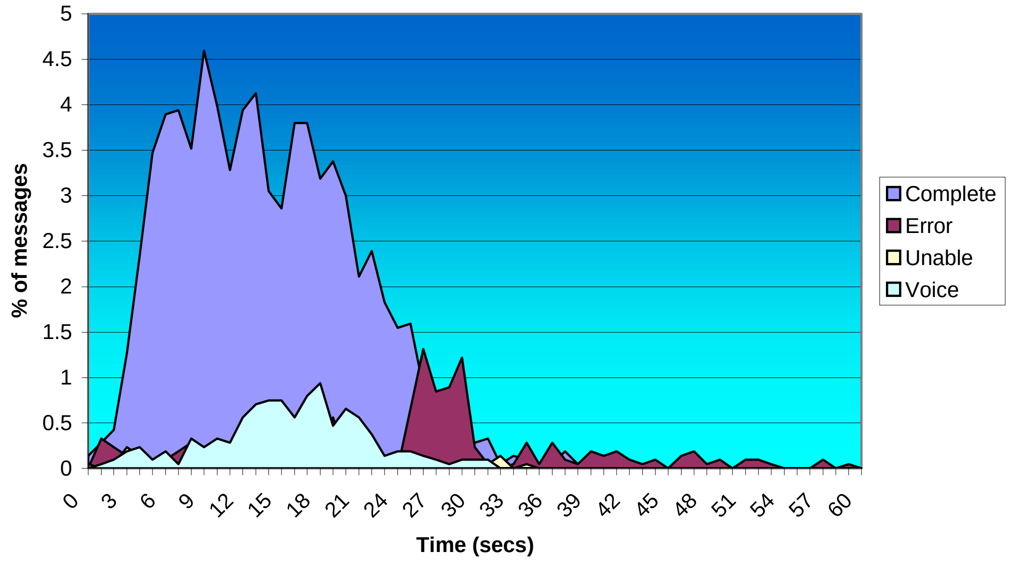
The air-ground datalink chain is shown in the next figure.



A transmission delay model is incorporated within the ATN-Lite in order to emulate the transmission delays of the communication chain. This delay is comprised of two components, the ATN router delay and the sub-network delay.

Each datalink message is delayed by the application of a delay model which reflects a Poisson distribution. The distribution of the message delay for each potential outcome observed during the simulation is shown in the following figure :

Datalink duration by outcome



4.2 Controller Working Position (CWP)

Each CWP consisted of:

- 28” colour display, providing a multi-window working environment with data input and information access facilitated by a mouse;
- individual telecom panels with push-to-talk facility, providing verbal link with all the other sectors;
- radio system with headset and foot switch for communication with pilots.

Each measured position was further equipped with an ISA input panel used by the controller for periodic input of a subjective workload assessment.

4.3 Human Machine Interface

The Human Machine Interface used in this experiment was the EATCHIP HMI, developed over the series of trials from results of ODID IV and PHARE.

Its major components included:

- the Radar Plan View Display (PVD) of the traffic situation;
- the aircraft tracks with Radar Labels presenting flight plan and current information. The information displayed and the colour of the Radar Label were dependent upon the aircraft planning state;
- the Extended Radar Label providing supplementary flight plan information;
- the Radar Toolbox permitting modification of the PVD display characteristics;
- the Preferences Tool enabling the controller to save and re-load a preferred display configuration ;
- the Sector Inbound Lists (SILs) displaying advanced information for aircraft planned to enter the sector;
- the Message IN and the Message OUT windows providing in-coming and out-going co-ordination messages exchanged with neighbouring sectors as well as ongoing datalink communications;
- the Dynamic Flight Leg providing display of the selected flight’s currently planned path within the Radar PVD, updated after route changes;
- Short-term Conflict Alert

The system did not provide medium term conflict detection or trajectory edition.

5. Experimental Plan

The experiment manipulated three experimental variables:

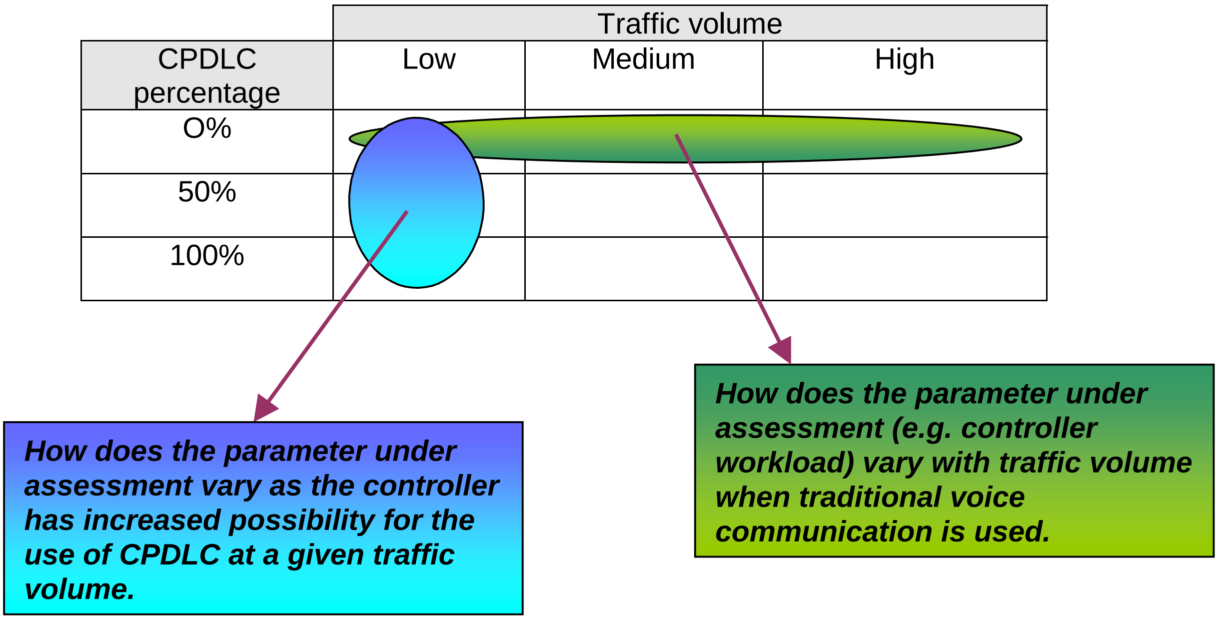
Experimental variable	Description	Number of levels
Controller role	The assignment of the two measured controllers to the role of PC or TC	2
% CPDLC-equipped aircraft	The % of the total traffic volume possessing a CPDLC capability	4
Traffic volume	The hourly demand for ATC services in sector YR	3

A full factorial design[1] with these experimental variables was planned calling for the completion of 24 (2*4*3) measured exercises.

The experimental design (and corresponding exercise schedule) aimed to meet several requirements simultaneously :

1. Allow required statistical comparisons to be made between different scenarios (see diagram below)
2. Allow measured controllers to work both executive and planning positions
3. Minimise the possibility for learning the traffic behaviour (simulator effect)
4. Minimise the number of distinct traffic samples that need to be created

The following diagram illustrates two different kinds of comparison that can be made as well as the question being asked when assessing data derived from the scenarios under investigation, in this case traffic volume and CPDLC percentage.



	Traffic volume		
CPDLC percentage	Low	Medium	High
O%			
50%			
100%			

How does the parameter under assessment vary as the controller has increased possibility for the use of CPDLC at a given traffic volume.

How does the parameter under assessment (e.g. controller workload) vary with traffic volume when traditional voice communication is used.

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[1] This is an experimental design in which each of the combinations of the levels of independent variables are assessed. If there are k independent variables and each has two levels then there is a requirement for 2^k exercises.

6. Simulation Programme

The simulation took place between 15 September 1999 and 28 September 1999 inclusive. This period was considered to be the absolute minimum required to provide a sufficient level of controller training and then to complete the different scenarios foreseen in the experimental plan.

6.1 Controller training

Whilst the two controllers manning the measured sector YR were current operational staff familiar with the sector, they were also less familiar with the EATCHIP HMI and also the ATC procedures to be employed in association with CPDLC. Neither had previously used a strip-less ATC system. As a result of this, the initial three days of the simulation were devoted to controller training. Based on previous experience, three days is considered to be the appropriate amount of time for familiarisation with the interface in order to ensure the validity of the measured exercises.

This training phase comprised both classroom style presentations as well as ‘hands-on’ training on the simulator. Specifically, the training addressed the following issues :

1. Overview of EUROCONTROL projects relating to SYSCO and CPDLC
2. The EATCHIP HMI
3. ATC procedures applicable to the management of datalink equipped aircraft
4. Task distribution within the sector team
5. Objectives and the conduct of the L2KBC simulation, including a briefing concerning the use of subjective workload measurement in the form of ISA.

The feed sector positions were manned by three operational controllers from the Romanian administration. Although essential to the smooth running of the experiment and realism, the feed sector positions took no part in the objective analysis of the simulation.

The feed sector controllers had all taken part in previous EATCHIP (or similar) experiments and were more familiar with the HMI on arrival. For this reason, the training of the feed sector controllers concentrated on the use of datalink and the operational procedures relating to the delivery of traffic to the measured sector.

6.2 Daily programme

The daily schedule of the simulation was constructed so as to permit the execution of a minimum of three exercises per day. A simulation exercise lasted for a period of approximately 90 minutes[1] during which one hour of measured data was gathered. The overall exercise schedule aimed to complete the 24 exercises required by the experimental plan. The sequencing of the exercises was performed so as to minimise the learning effects associated with repetition of the traffic samples.

The simulator platform proved reliable throughout the simulation period and 21 of the planned 24 exercises were completed.

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[1] Including “warm-up”, prior to measured hour and any short questionnaires to be completed at the end of the exercise.

7. Analysis of Results

7.1 Information sources

The simulation analysis is based on two sources of data. The first concerns the subjective feedback i.e. the comments made in questionnaires and to the observer during the simulation exercises. This type of data is useful not only as a direct indication of the controllers' perception of the concepts but also as an indicator of how representative the simulated exercises were.
The second source is the recorded or objective data which covers several different systems :

1. recordings of aircraft profile information, representing both the filed flight plans in the traffic sample and the aircraft 4D trajectory flown during simulation exercises;
2. recordings of the interaction of the controllers with the HMI;
3. recordings of controller verbal communications (number and duration of r/t communications and telephone calls);
4. the ISA workload measure. Although traditionally considered as a subjective (based on controller opinion) measure, the ISA responses can, under the correct circumstances, be subjected to statistical analysis in order to detect for workload differences between scenarios.
5. inputs made by pilots in response to control instructions

For analysis purposes the recorded data have the advantage that they can be more easily associated with a particular set of experimental conditions .e.g. traffic sample, control position, thereby rendering them more useful in the comparison of results recorded under different conditions. Recorded data is also invaluable as a means of supplementing the subjective feed-back provided by the controllers.

Throughout the simulation exercises the controllers entered subjective workload estimates at two minute intervals at both radar and planning conditions. This data was entered via a keypad incorporating a set of five buttons. The controllers were instructed prior to the simulation as to the meaning of each of these buttons, as indicated in the table below, and requested to adhere closely to this definition in order to ensure the uniformity and validity of the data.

Button description	Workload status
Very Low	There is little or nothing to do
Low	More time is available than necessary to complete the required tasks
Medium	The level of ATC work is stimulating but all tasks are under control; more tasks could be accepted
High	The controller is working at the limit of available capacity and no further tasks can be accepted
Very High	The workload capacity limit has been exceeded and some tasks are being shed as a result

7.2 Analysis of Questionnaires & Debriefings

It should be borne in mind that the subjective comments described in the following Sections were obtained from only the two measured controllers. Whilst providing useful feed-back, these comments cannot be considered as necessarily representative of the wider controller population. They should therefore be used to provide information for the development of datalink as well as the importance of the underlying HMI and operational procedures but should only be considered as indicators of potential areas of concern once larger scale studies or implementation commence.

7.2.1 Simulation Environment and execution

It is useful to place the subjective feedback of the participants into context by first considering their overall impressions of the experiment. Clearly if they were unhappy with the structure of the exercises or felt that the lack of realism was too significant then this would draw into question many of the findings of the experiment.

The controllers stated that they understood the objectives of the simulation and the manner in which the exercises would be conducted in relation to the experimental planning.

The principal problem cited by the controllers throughout the simulation was that in the absence of paper strips the system did not provide sufficient means to perform advanced planning and to maintain a satisfactory overview of the global traffic situation.

The EATCHIP philosophy of a strip-less HMI has been developed over several years and contains a number of distributed elements whose role is to substitute for the removal of strip-based information. Typical “planning” methodologies evoked with this system include scanning the sector inbound lists, verifying conflict free trajectories at entry and exit using the dynamic flight leg for route / conflict information and performing electronic co-ordination with neighbouring sectors as and when necessary.

Although this working method was evoked during both the training phase and in discussions during the simulation, the controllers stated that the sector inbound lists were confusing and that they could not maintain a global overview of the state of the traffic at sector entry and exit. This situation resulted in both higher workload perceptions for the controllers and also the sentiment that they were performing reactionary control, often “behind the traffic”. In general, the planning role became one of tactical support to the radar controller.

This assertion by the controllers was an unexpected finding of the simulation, as it had never been raised in any of the previous simulations, but it should be borne in mind that it was a sentiment relating to the interface itself rather than related to the specific issue of datalink.

Whilst any absolute measures of workload are doubtless affected by this condition, the relative measures of objective data are still considered valid and useful.

The controllers considered the traffic samples suitable for the experiment although some of the more complex situations encountered during “real-life” such as requests for direct routes from preceding sectors were not simulated with enough regularity.

Toward the end of the simulation there was some degree of familiarity with the samples. Ideally, more traffic samples would have been created in order to circumvent this problem but it did not prove practical in the time available for simulation preparation.

7.2.2 Air Ground Datalink Concepts

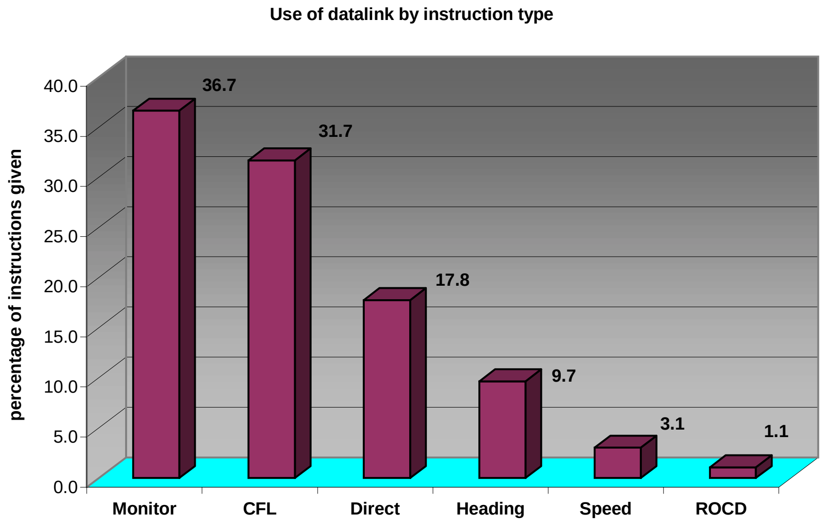
The controllers considered that the concept of datalink operations was easy to understand. They felt that the associated procedures were easy to learn and to work with.

On the specific advantages of datalink and its representation on this interface the controllers cited :

- Simplicity of Assume and Transfer (“Monitor”) operations, particularly Transfer
- More rapid assignment of Cleared Flight Level (CFL)
- Harmonisation of all relevant information within the radar label

Datalink was not considered useful for the transmission of heading instructions as often the associated delay could render invalid the control strategy being applied.

The use of datalink for the different instruction types is indicated in the following figure. The Assume and Transfer actions have been grouped together under the criteria “Monitor”.



It was stated that any potential revision of task allocation between controllers following the introduction of datalink should consider the allowable “dialogue paths”. It was stated that dialogue should be between adjacent sector planners, within the sector team **but never** sector planner and aircraft.

7.2.3 Level of Service

The controllers were themselves unsure as to whether datalink enables the provision of a better service to the airspace user. It was pointed out that some actions take longer via CPDLC and that it is necessary to allow for longer pilot response times. The general view seemed to be that CPDLC could allow more aircraft to be handled, that the availability of the CAP information improved the data quality but that as a result of the high workload associated with performing the planning task, the advantages of CPDLC were not immediately apparent from any perceived workload reduction.

7.2.4 Safety

Comments pertaining to situational awareness, or lack thereof, were frequently made regarding the interface as described above.

A number of useful comments were made concerning the potential loss of situational awareness arising from what can be referred to as “voice memory”. The controllers considered that the action of transmitting verbal instructions to aircraft provides for more reliable memory recall of actions recently taken. They expressed that the relative simplicity of modifying the parameters of datalink aircraft (simple click) would lead to a reduced knowledge or memory of recent strategy. Although this aspect could not be explored in more detail it was considered sufficiently important by the controllers to merit further investigation.

As a specific example, it was considered that when assuming aircraft in high traffic situations, the simplicity of the action could result in a non-optimal integration of the aircraft when compared to the normal voice and radar identification. The controllers identified the need to effectively dwell on the label to capture the current and intended trajectory.

Clearly these issues merit further study so as to be able to define more clearly any eventual training modifications required for controllers following the introduction of datalink.

It was commented that with CPDLC there was a longer delay between issuing an instruction and seeing the response than there would be with r/t. The general view was that the delays were just acceptable but that the response would need to be much faster in a real system.

It is important that controllers capture any error or unable messages immediately so as to be able to re-initiate the datalink communication or revert to voice.

There was concern that the reduction of the use of voice communication would lead to a loss of awareness on the part of pilots as to the current state of controller workload, potentially leading to many more pilot requests for preferential routings or levels.

In a mixed datalink environment there may be errors induced such as updating the system for a non datalink equipped aircraft but neglecting to verbally transmit the order to the pilot.

7.2.5 HMI

The controllers found the methods and messages used for data input were easy to learn, if not always efficient. They considered that the datalink HMI concept (callsign framing etc.) was easy to understand. It was considered easy to distinguish between datalink and non-datalink flights and also to follow the status of a datalink dialogue at the aircraft label.

On many occasions during higher workload situations, particularly in the High (200%) traffic sample , the controllers missed the initial “silent call” of a datalink aircraft following transfer from the feed sector. In practice, the task of scanning at the sector periphery and informing the radar controller of the necessity to assume an aircraft onto the sector frequency was often performed by the planning controller.

Although the controllers stated a preference for giving heading instructions via r/t, they did state that the method of entering heading values to the system was unnecessarily complicated. For example, in the normal operations of sector YR, about 85% of heading instructions are given as deviations from the current value (including the instruction to maintain the current deviation). The system input window did not easily permit such deviation or maintain instructions to be entered.

In general, the HMI for the transmission of datalink instructions was considered to lack a certain amount of basic functionality. In particular, it was cited that there was no possibility to transmit via datalink instructions to prepare the pilot e.g. “expect descent at …”.

There was also no possibility to give multiple concurrent instructions via datalink, for example level and transfer. Similarly, following an input error, no revision of the data could be made prior to the reply without reverting to the use of voice. This is a deliberate design decision as the management of such non sequential message sequences is complicated at the HMI level.

The “airspace alert” functionality at the HMI could not be cancelled and frequently hampered access to the label for the transmission of datalink instructions.

A number of specific comments were made about the EATCHIP HMI which were not directly related to datalink. These are not included here but addressed principally :

1. the incomplete nature of the silent co-ordination
2. alternative methods for accessing certain important parameters
3. additional information which should be available to the controller

7.2.6 Controller Access Parameters (CAP)

The availability of CAP information was considered very useful and could potentially lead to a reduction in the number of r/t transmissions requests for aircraft information[1].

Both speed and heading information were considered particularly useful. For vertical rate data, the controllers were happy with descent information but not climb information as the latter could be misleading.

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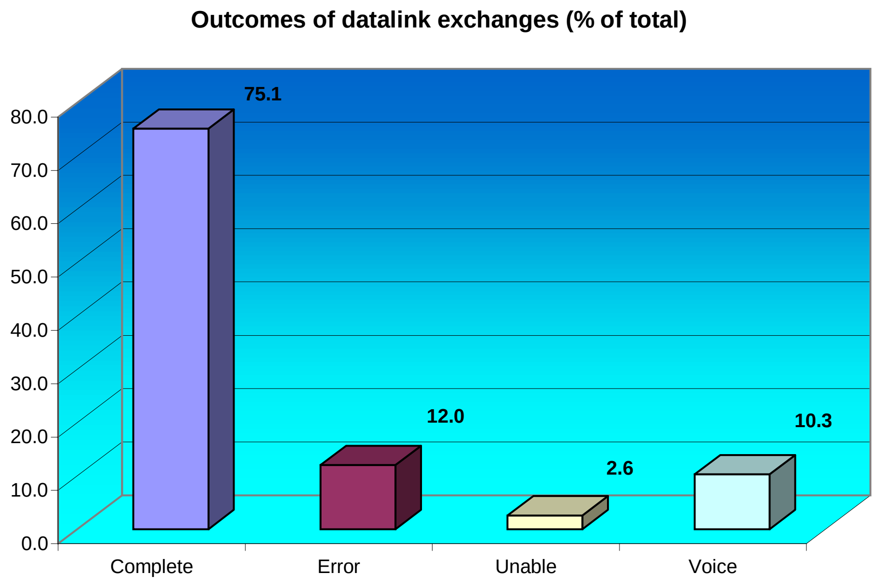
[1] It is not possible to quantify this reduction as CAP data was only available in those scenarios where some percentage of the aircraft possessed a CPDLC capability

7.2.7 Error messages

The controllers considered the frequency of error messages to be sometimes unacceptable and the occurrences of datalink transmission or reception errors could be a major contributory factor to overall workload. An analysis of the outcome of each datalink message employed in the simulation is shown below

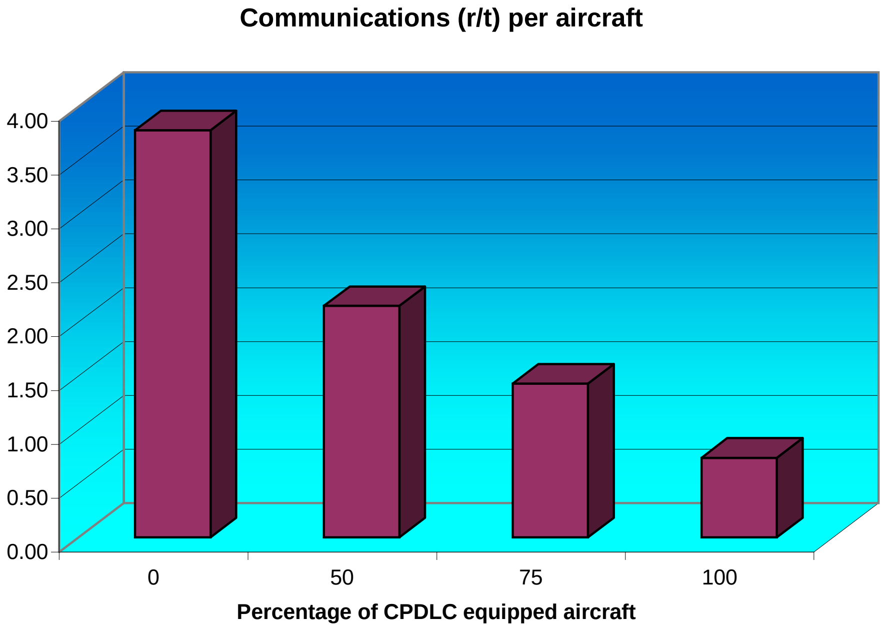


7.3 Data analysis

7.3.1 Workload assessment

Clearly, the presence of datalink will have an impact on the number of r/t communications carried out with aircraft. A secondary effect is the availability of downlinked aircraft parameter (CAP) data which is also expected to reduce the number of communications as a result of the removal of the need to query aircraft current parameters.

The number of r/t communications performed per aircraft is directly measurable from the recorded data. The analysis is performed according to the percentage of datalink equipped aircraft within the traffic sample and the result is shown in the following figure :

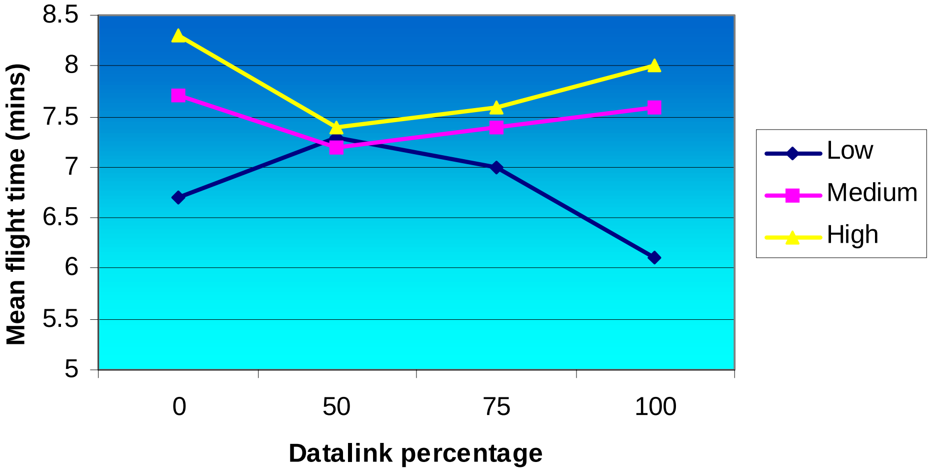


Analysis of the communication workload showed a reduction of 45%, 61% and 84% for the 50%, 75% and 100% datalink scenarios respectively. This effectively means that there is a slight "lag" arising from those instances when the controllers adopt the use of voice for clearances for datalink equipped aircraft be it intentionally due to time constraints or complexity of the instruction or following a datalink transmission error.

An aim of this simulation was also to investigate to what extent the reduced communication workload manifested itself in a reduction of the subjective workload measure (ISA) recorded by the controllers during the exercise execution. This aim was severely affected by the assertion on the part of the controllers that the HMI did not allow them to satisfactorily perform the planning task with a consequential impact on their perceived workload.

7.3.2 Level of Service

For a simulation the size of L2KBC with only a single measured sector, any objective measure of level of service e.g. adherence to user preferred trajectory can at best be expected to provide only a broad indicator of performance. A measure of the flight time within the sector has been studied as indicated in the following graphic. Whilst there is consistent variation arising from the traffic volume increase (Low, Medium and High), no consistent behaviour related to the variation in datalink percentage can be observed.



An analysis of the percentage of time spent at the aircraft Requested Flight Level (RFL) was also performed and, again, no consistent results were obtained. The variation in the controller r/t communication rate arising from datalink has been used to provide some tentative indication as to the potential workload reduction and hence capacity increase over the wider LINK 2000+ geographical area. This analysis has been made using estimates of the relationship between workload and capacity (based on the EUROCONTROL HQ's Capacity Analyser – CAPAN) as an input to a detailed ATFM simulation. The results of this study are further described in Section 8.

7.3.3 Safety

An analysis has been made of all occurrences throughout the simulation where the applicable separation minima (5nm lateral and 1000 / 2000 feet vertical) were simultaneously violated. As to be expected, such events were very infrequent (less than one per exercise) and certainly do not permit a study of any link between their frequency and the configuration of the simulation independent variables (traffic volume and datalink percentage). Those losses of separation minima that did occur all consisted of minor losses. The simulation highlighted the most serious safety issues as being :

1. Potential loss of situational awareness for controllers
2. The importance of not allowing the planning controller to perform inputs on behalf of the radar controller, or at least to define clear task allocations within the sector team.
3. The importance of only using the CPDLC message system for non time-critical instructions.

8. Potential Benefits within LINK 2000+ Geographical Area

Following the L2KBC simulation, a number of the objective data sets have been analysed in conjunction with a series of fast-time simulation studies as a means to determine the likely impact of the availability of datalink communication within the LINK 2000+ geographical area.

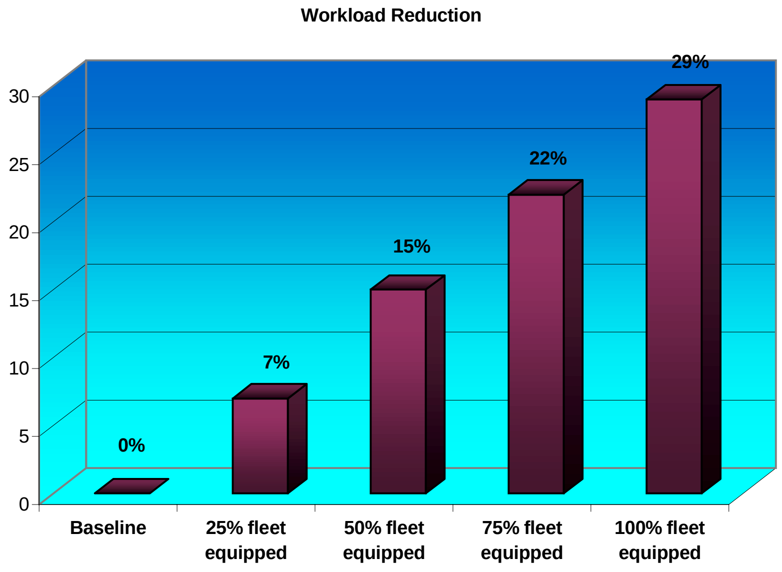
It is not the objective of this report to provide a detailed explanation of this analysis but it is nevertheless pertinent to include some of the major findings.

8.1 CAPAN fast-time simulation study

CAPAN (Capacity Analyser) is a Task based fast-time simulation tool which generates workload estimates based on the passage of traffic in a simulated airspace and the different discrete ATC events that such a traffic pattern and applicable ATC procedures generate. The specific ATC tasks covered within CAPAN include Flight Data Management, Coordination, conflict search, r/t communication and the Radar Tasks. For each ATC Task, the controller responsible (Executive Controller, Planning Controller or Assistant) is specified as a parameter to CAPAN along with an associated execution time which represents the time during which the controller is fully occupied for the execution of the task.

A CAPAN simulation was conducted in order to study the potential workload benefits associated with the introduction of CPDLC for varying fleet equipage rates. For the CAPAN study, the simulated airspace corresponded to Karlsruhe UAC with 14 sectors open. The parameters used for the Baseline scenario represent the actual working practices at Karlsruhe UAC, and were already defined with DFS Controllers for the EAM04 Fast Time Simulation of German Airspace.

The parameters (task duration) for the Data Link Scenarios were defined by operational experts[1] The reduction in radar controller workload, derived simply from the total task execution times observed within the CAPAN study is indicated adjacent :



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[1] The communication task time for CPDLC is not set to zero since there are still searching and monitoring tasks to be performed

The figures obtained within the CAPAN study represent an overall reduction in workload based on the changed ATC task times as a result of the introduction of CPDLC for various fleet equipage scenarios.

Within the L2KBC simulation analysis, on the other hand, it has been possible to determine the reduction in r/t communication workload. The figures from the two simulations are provided in the following table :

Fleet equipage (%)	L2KBC observed **r/t reduction** (%)	CAPAN predicted overall **workload reduction** (%)
50	45	15
75	61	22
100	84	29

The figures obtained in both L2KBC and the independent CAPAN study for workload reduction are broadly consistent in that the CAPAN figures represent approximately 35% of the L2KBC figure for each datalink equipage rate. Furthermore, the value of 35% is considered by most fast-time simulation experts to be a reasonable estimate of the proportion of total workload represented by r/t communications.

Fast-time simulation tools such as CAPAN and RAMS also incorporate capacity assessment methods based on a perceived workload threshold for a controller during a given period. Both CAPAN and RAMS employ a threshold of 70% i.e. the sector capacity is considered to be attained when the total task execution time attains a value of 70% of the period under assessment, usually 3 hours.

The capacity increases predicted by CAPAN can currently not be endorsed by L2KBC due to the factors relating to the difficulty of the planning task and the loss of situational awareness described earlier. The coherence of the two communication workload figures is, however, worthy of note.

8.2 COSAAC ATFM simulation

An ATFM simulation using the Common Simulator to Assess ATFM Concepts (COSAAC) has been performed employing the r/t workload benefits observed in L2KBC and an estimate of their likely impact on capacity. This simulation has been performed for the LINK 2000+ geographical area. This simulation was performed in order to provide an initial estimate on the impact of ATFM (delay reduction) measures following the introduction of CPDLC. For the purposes of the simulation it was assumed that the capacity figures were applied uniformly throughout the LINK 2000+ geographical area.

The delay reduction figures that were derived are presented in the following table with the LINK 2000+ area in red:

A/C Equipage	**0% datalink**	**50% datalink**	**75% datalink**	**100% datalink**
Capacity Gain	**0%**	**8%**	**11%**	**14%**
BELGIUM	2226	1552	2187	2221
GERMANY	2916	2770	817	510
MAASTRICHT	46779	41713	32142	29049
UNITED KINGDOM	2014	1125	644	553
NEDERLANDS	96	96	96	90
NORWAY	10	1	0	0
SWEDEN	5	0	0	0
CANARIAS	78	36	15	15
SPAIN	20739	8332	3857	3561
FRANCE	37837	19161	14178	12193
ITALY	25231	13872	9849	7384
CZECH	1933	519	396	294
PORTUGAL	18	0	0	0
SWITZERLAND	38601	14607	9661	4045
TOTAL	178483	103784	73842	59915
Total for LINK2000+ geographical scope:	176517	103264	73446	59621
Decrease of Delay by:		**41%**	**58%**	**66%**

9. Conclusions and Recommendations

The L2KBC simulation was performed during September 1999 and a large amount of useful feedback, both subjective and objective, was obtained.

1. Controllers reported that the lack of paper strips did not permit them to perform advanced sector planning in the manner to which they were accustomed and that there was a consequential impact on the workload measures obtained during the experiment. This was an unexpected finding, particularly considering the relatively advanced state of HMIs built using similar principles, notably Denmark/Sweden Interface (DSI).

   Future studies should allow extra time, if necessary, for operational training in order to ensure that the maximum benefit is gained from the simulation.

2. The controllers considered that the concept of datalink operations was easy to understand and that the associated procedures were easy to learn and work with. Specific advantages of datalink and its representation on this interface included :

   - Simplicity of Assume and Transfer (“Monitor”) operations, particularly Transfer
   - More rapid assignment of Cleared Flight Level (CFL)
   - Harmonisation of all relevant information within the radar label

3. Controllers provided much useful feedback in relation to the safety of CPDLC operations. A number of useful comments were made concerning the potential loss of situational awareness arising from what can be referred to as “voice memory”. The controllers considered that the action of transmitting verbal instructions to aircraft provides for more reliable memory recall of actions recently taken. They expressed that the relative simplicity of modifying the parameters of datalink aircraft (simple click) would lead to a reduced knowledge or memory of recent strategy.

   Although this aspect could not be explored in more detail it was considered sufficiently important by the controllers to merit further investigation. Further studies should be conducted into ground situational awareness as well as tasks allocation within the sector team.

4. Some use of the data from L2KBC has now been made in conjunction with fast-time simulation studies and this exercise has been briefly outlined in this report.

   Further studies are required in order to explore the relationship between CPDLC operations and the underlying HMI as part of the datalink implementation programme.

5. The availability of CAP information was considered very useful and could potentially lead to a reduction in the number of r/t transmissions requests for aircraft information.

6. The experimental planning methodology proved to be practical in the time allocated for the experiment

References

1. Harvey *et al* EATCHIP III Evaluation and Demonstration – Experiment 3B

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