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FAA ODID IV
EN ROUTE BASELINE COMPARISON SIMULATION FINAL REPORT

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FAA ODID IV EN-ROUTE BASELINE COMPARISON SIMULATION FINAL REPORT

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Abstract:

This report describes the results of the FAA ODID Real-Time Simulation and includes :

A description of the ODID system as assessed by the FAA
Controller Operational commentary pertaining to the simulation
Results of the objective data gathered during the simulation and a comparison with the Plan View Display system.

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ABBREVIATIONS

Abbreviation	De-Code
AFL	Actual Flight Level
ahd	Assigned Heading
arc	Assigned Rate of Change
ARTCC	Air Route Traffic Control Centre
asp	Assigned Speed
ATWIT	Air Traffic Workload Input Technique
CARD	Conflict And Risk Display
CFL	Cleared Flight Level
CHI	Computer Human Interface
CID	Computer Identification Number
CWP	Controller Working Position
CZW	Conflict Zoom Window
DCRD	Data Controller Computer Readout Display
DSR	Display System Replacement
EATCHIP	European Air Traffic Control Harmonisation and Implementation Program
EEC	EUROCONTROL Experimental Centre
ERL	Extended Radar Label
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
EUROCONTROL	European Organisation for the Safety of Air Navigation
FDB	Full Data Block
FL	Flight Level
Freq	Next Sector Frequency
GUI	Graphical User Interface
HMI	Human Machine Interface
ISA	Instantaneous Self-workload Assessment
MTCA	Medium Term Conflict Assistance
NS	Next Sector symbol
ODID	Operational Display and Input Development
PEL	Planned Entry Level
PFL	Planned Flight Level
PLC	Planning Controller
PS	Position Symbol
PVD	Plan View Display
REL	Released
RFL	Requested Flight Level
RPS	Radar Position Symbol
SAC	System Assisted Co-ordination
SIL	Sector Inbound List
SI	Sector Identification
SSR	Secondary Surveillance radar
sp	Ground Speed
STCA	Short Term Conflict Alert
tas	True Airspeed
VAW	Vertical Aid Window
XFL	Exit Flight Level
XPT	Exit point

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EXECUTIVE SUMMARY

The joint FAA/EUROCONTROL simulation involving the Operational Display and Input Development (ODID) system was devised to compare ODID with the FAA current en route Plan View Display (PVD) system. Results from this comparison may help FAA strategic air traffic control (ATC) automation investment decisions. ODID demonstrated technology concepts and principles for human-machine interface design.

The ODID simulation intended to provide data comparable to the PVD baseline data sets that had previously been established for a different purpose. Preparations included adapting the PVD baseline Washington ARTCC airspace and traffic samples for simulation use. The PVD baseline traffic sample was based on System Analysis and Recording data and represented a 90th percentile day in traffic volume for the facility from September, 1992. A provision for Added Traffic exercises allowed for comparing use of ODID under a range of traffic volumes which was 144% of the ODID baseline traffic count. Measurement techniques included reduction of ODID system recordings, questionnaires, post-exercise debriefing, video recording, and the Instantaneous Self-Assessment (ISA) workload measurement technique.

Eight controllers were drawn from ARTCCs and FAA headquarters, with one controller current and another controller previously certified on the same Washington ARTCC airspace. The controllers received training on the ODID system and the airspace and procedures. The decision to start the ODID measured exercises using the baseline traffic samples was fully supported by the controllers. During the ODID simulation, controllers also assessed a technology demonstration of the EUROCONTROL Highly Interactive Problem Solver (HIPS) conflict resolution and planning tool.

Major findings from the ODID-PVD baseline comparison organised according to the baseline measurement operational constructs were:

- **Capacity**

With ODID there was a reduced average flight time in the two low altitude sectors (reduction of up to 1.4 minutes), and the variation in flight times was about half suggesting more consistency compared to the PVD baseline. With ODID there were fewer altitude changes per aircraft in three of the four sectors due, in part, to controllers' use of System Assisted Co-ordination (SAC). The controllers considered SAC to be the single most useful facility in ODID. SAC messages were sometimes generated as frequently as 1 per 2.5 aircraft, and frequently involved changes to sector exit points and flight levels.

- **Safety**

There were three losses of separation with ODID, one of which was viewed as an endorsement of ODID technology due to its prediction in the displayed Vertical Aid Window (VAW). The other two losses were in different manners related to the simulation. ODID Medium Term Conflict Assistance (MTCA) tools were limited in use for strategic deconfliction due to the implementation of trajectory recalculation contained in the ODID software version. However, the VAW was displayed at a ratio exceeding one per aircraft, primarily for traffic inbound to the sector to check for potential conflicts.

- **Performance**

With ODID there were fewer simulation pilot speed and heading changes per aircraft due, in part, to controllers' use of MTCA tools and SAC. Controllers considered that the ODID principle of displaying minimum information and accessing supplementary information on request co-located on the radar display has the potential to eventually replace paper strips. The ODID Flight Leg, Sector Inbound List and dialogue design were all found useful, as was the use of colour, although there was considerable discussion about the particular colours used in ODID.

- **Workload**

With ODID, between sector communications were reduced by 50%. Controllers used SAC, rather than land line calls, to silently co-ordinate aircraft altitude, speed, heading, and direct routing changes.

It was concluded that the simulation had provided the FAA with additional information concerning the means whereby new ATC technologies may contribute to controller productivity or benefit the user.

It was recommended that ODID principles and controllers' inputs be integrated into a technical specification for a future product improvement of the Display System Replacement program.

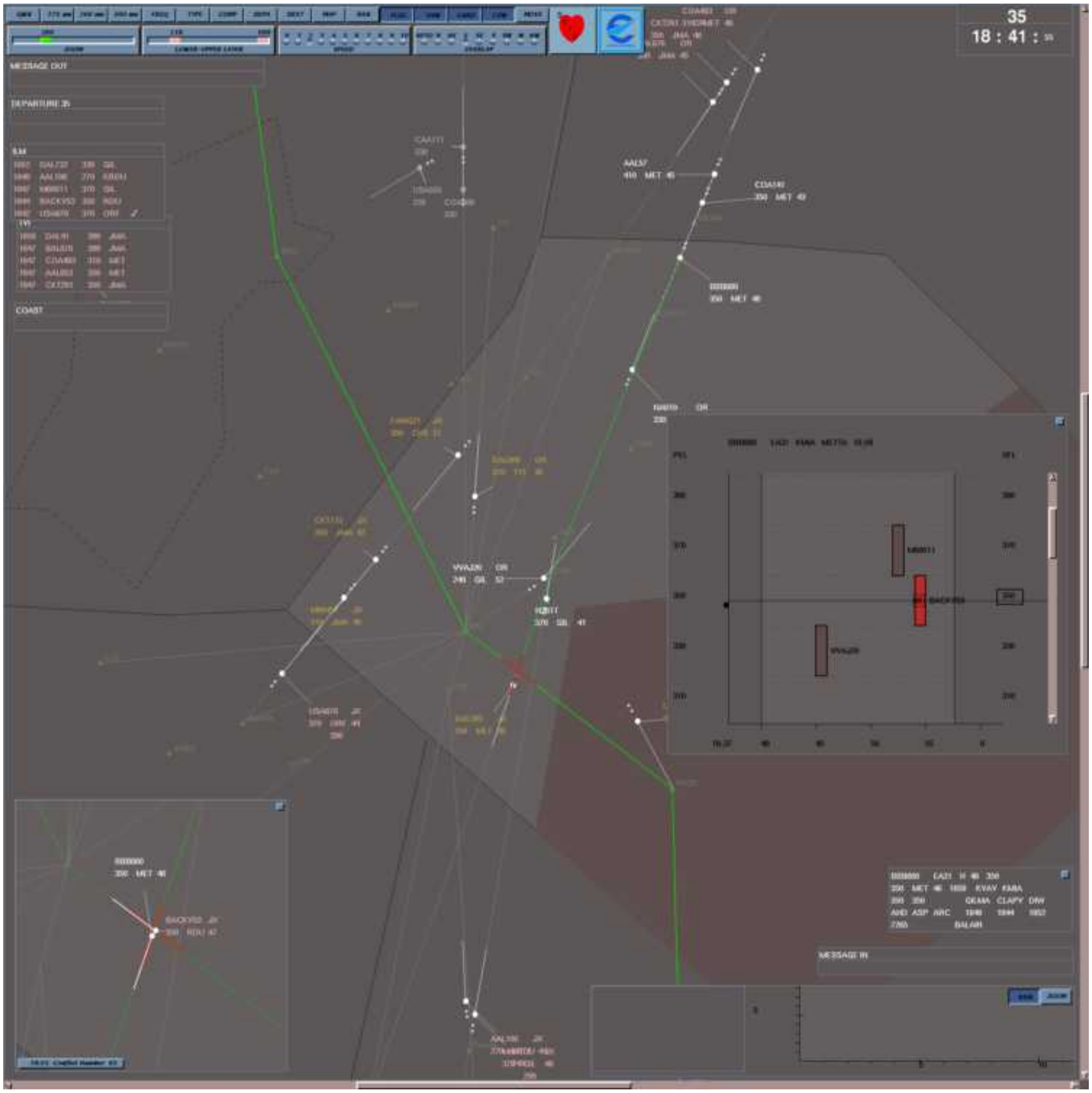


Figure 1 : Sector 35 ODID Controller Working Position

1. INTRODUCTION AND OBJECTIVES

The **FAA / EUROCONTROL ODID** simulation was conceived by the FAA to compare the levels of en route service provided by the current FAA Plan View Display (PVD) facilities with a future Controller Working Position (CWP). This future system was centred around the ODID IV technology. The approach used in this simulation was designed to help answer strategic investment decisions on Air Traffic Control (ATC) automation in the context of the FAA Display System Replacement (DSR) program (References 1 and 2).

Specifically, the simulation was designed to provide a comparison of ODID with baseline data collected on the FAA PVD system. The simulation was also designed to provide the FAA with increased understanding and insight into the concepts and functions of an advanced CWP which employs colour, graphics, conflict tools and dynamic system interaction using a three button mouse.

This joint project was part of the continuing co-operation between the FAA and EUROCONTROL. The simulation was conducted at the EUROCONTROL Experimental Centre (EEC) between 22 July 1996 and 09 August 1996 and referred to as EEC Task SA5.

The primary objectives of the simulation as proposed by the FAA were to :

- provide a comparison of the ODID functions and the PVD baseline;
- evaluate the impact of increased air traffic on an ODID baseline.

The assessment of the ODID system for increased traffic involved traffic samples prepared jointly by the EEC and FAA operational staff familiar with the simulated airspace.

Secondary objectives were to :

- provide an infrastructure which permits future FAA evaluation of EUROCONTROL study projects by controller participation;
- provide the ability for the FAA and EUROCONTROL to share comparable analysis data concerning future study projects.

The experimental plan for this simulation was dictated by the requirement to provide comparative data to the PVD baseline. The PVD baseline simulation had previously been carried out at the FAA Technical Centre during January 1995, the objective of which was to provide measurements relating to an en-route centre employing the Host Computer, Plan View Display and the M1 console. The results of this baseline simulation are provided in References 3 and 4.

The PVD baseline simulation identified five operational constructs which could be used for system assessment (Reference 5). These were :

- Capacity;
- Safety;
- Performance;
- Workload;
- Usability.

The experimental plan for the FAA ODID simulation therefore aimed to replicate this analysis where appropriate although the vastly differing HMI of ODID and the PVD implied that certain baseline PVD measures would not lend themselves to direct comparison with ODID. Furthermore, a number of constructs which would normally form part of the analysis methodology of an EEC simulation fell outside the scope of this comparative analysis and were not used.

This report is divided into several distinct sections. Firstly, a description of the ODID system as simulated is provided, along with the operational review from the participating US controller team. Secondly, the results of the comparative analysis of ODID and PVD are presented. Thirdly, results from the first two sections are integrated in a final set of findings, conclusions and recommendations.

2. ODID DEVELOPMENT IN EUROCONTROL

The EUROCONTROL Experimental Centre has run simulations for four generations of ODID, and a number of simulations for other National Administrations employing ODID technology.

The first ODID simulation, **ODID I**, studied co-ordination procedures using electronic transmission of data and methods of data display where colour represented direction of flight and outstanding tasks. A three line data block in monochrome was also evaluated.

ODID II used the findings of the first simulation on colour and co-ordination and further evaluated data displays and input functions under different traffic loads. Two co-ordination methods were studied: on a systematic basis and on receiving controller initiation.

The **ODID III** simulation studied two different organisations: tabular data displays with graphical aids - electronic strips - proposed by France, and, graphical displays with information windows, proposed by Switzerland. It attempted to exploit the new technology associated with large raster scan displays and graphic processors providing the controller with a significantly enhanced automated environment.

ODID III maintained the concept of Planning (Data) and Radar controllers in a sector. The planner was assisted by a set of dedicated entry and exit planning tools and a conflict risk display. Colour was used to indicate the state and control responsibility of a flight and to attract the controller's attention to outstanding tasks. Controllers used a mouse input device to interact with the system and data input ensured current system profiles, and permitted co-ordination between Centre and sectors by means of pre-determined electronic co-ordination messages.

ODID IV provided the controller with a working environment where essential data was displayed on a priority basis with supplementary information available on request - building on ODID III. The control environment was a full ATC environment simulating from the runway to en-route.

ODID IV used colour to indicate aircraft planning status, co-ordination, and conflict and urgency situations. Interaction between the controller and the system was provided through a three button mouse and by clicking on displayed objects data could be entered or information displayed on a temporary or permanent basis. The use of paper strips for advance planning information, conflict detection and noting of controller instructions was replaced by tabular data displays, Medium Term Conflict Assistance (MTCA) tools and an interactive radar label. A System Assisted Co-ordination function provided for inter-Centre and inter-sector co-ordination via the use of predefined message formats and the application of colour for outstanding co-ordination. The results of the ODID IV simulation are described in Reference 6.

Since the advent of **ODID IV**, a number of National Administrations have participated in hands-on training, evaluation and live trials of the Controller Working Position. The ATC system development programs ongoing in many National Administrations in Europe as part of the European Air Traffic Harmonisation and Implementation Program (EATCHIP) are exploiting many aspects of the ODID Human-Machine Interface (HMI) and principles for operational use.

3. FAA ODID SIMULATION

3.1 PREPARATION

The FAA ODID SA5 simulation was prepared by the EEC with assistance from the FAA. Traffic samples and static airspace data were provided by the FAA and adapted for simulation use by the EEC. ATC working procedures used during the simulation were in accordance with Letters of Agreement and other operational information as were defined for the Washington Air Route Traffic Control Centre (ARTCC). The same Washington Centre airspace used in the PVD baseline simulation was used in SA5.

Documentation for this simulation, prepared by the EEC in conjunction with the FAA, included a full Facility Specification describing the technical, operational and analysis requirements to be met by the simulation environment. (References 7, 8, and 9). Additional documentation included Controller and Pilot Handbooks and Reference tables.

Project Management, deliverables and responsibilities were defined in the SA5 Project Plan (Reference 10).

A pre-simulation ODID training course was given by EEC and FAA operational staff at the FAA William J. Hughes Technical Centre. The training course was designed to familiarise the participating controllers with the following :

- The FAA ODID simulation and the EEC;
- The simulation objectives;
- The ODID concept;
- ODID Computer Based Training Package;
- Washington ARTCC airspace and procedures.

The Computer Based Training package, supplemented by classroom exercises, demonstrated the full range of ODID technology to the controllers using interactive techniques and a HMI closely replicating that of the ODID system.

Static airspace data validation took place at the EEC during May 1996. This allowed refinement of the traffic samples in order to ensure that profiles would allow correct message transfer in the ODID environment and also permitted initial validation of the geographical environment.

Operational acceptance took place at the EEC during July 1996 and permitted final validation of the traffic samples and the simulated environment.

3.2 THE PARTICIPATING CONTROLLERS

The ODID controllers were drawn from en route facilities across the United States and FAA headquarters. Six of the eight ODID controllers were current full performance level controllers at their facilities. One of these six ODID controllers served as a controller in the PVD baseline simulation and was a currently certified controller in the Washington ARTCC airspace used in this study. Another ODID controller had been a certified full performance level controller in this airspace. The other two ODID controllers were an area manager and a headquarters ATC staff specialist having previously been certified full performance level controllers in en route facilities.

All twelve PVD controllers in the baseline simulation were or had been certified full performance level controllers in the same Washington ARTCC airspace.

Other background information comparing ODID and PVD controllers is shown in the following table.

Table 1:

Background Survey Results	PVD	ODID
Average age	34	39
Years of ATC experience	10.6	13.9
Years of experience using the PVD	8.1	11.8
In the past year the number of months actively controlled traffic.	10.7	9.2
Evaluation of one's own ATC skill (rating scale: 1 = very low, 8 = very high).	7.2	6.9
Satisfaction with PVD/M1 console (rating scale: 1 = very low, 8 = very high).	6.2	5.4

During the ODID simulation exercises one ODID controller withdrew from participation at the conclusion of the baseline traffic exercises and was not available for the added traffic exercises.

3.3 MEASUREMENT TECHNIQUES

The data reduction required for this simulation used standard EEC simulation recordings and analysis techniques. These included :

Table 2 :

Data Source	Description
Air data	All aircraft profile information and sector occupancy
Pilot Orders	All pilot inputs to the system in response to controller instructions
Telecom	A record of the timing of all sector/sector and controller/pilot communications
CWP	All controller inputs to the system and related system responses
ISA	Instantaneous Subjective Assessment. The controller was prompted by the system to rate current workload on a score of 1 to 5 every two minutes
NASA TLX	A subjective workload assessment completed at the end of each exercise.

In addition the SA5 simulation employed video recordings, debriefing sessions and controller questionnaires.

Debriefings were conducted by the FAA and EEC Project Team throughout the duration of the simulation. These debriefings were typically with one or two controllers and allowed for informal discussion of issues relating to the ODID system and in particular the relation with the PVD. The information gathered during these debriefs was presented to the controllers in a debrief caucus at the end of the baseline simulation exercises and these results are described in detail in Section 4 under the Controller Operational Review sections of the ODID description.

Detailed questionnaires were prepared by the EEC and FAA. These questionnaires addressed ODID HMI and functionality, and comparisons between PVD and ODID regarding controller tasks. A set of PVD baseline questionnaires was also used. The controllers were asked to complete these questionnaires at strategic points during the simulation.

The recorded data from each simulation exercise were reduced according to Reference 8 in order to provide sector level and time based data in EXCEL format for technical analysis.

3.4 THE SIMULATED ENVIRONMENT

3.4.1 THE CONTROLLER WORKING POSITION

The ODID IV CWP consisted of :

- Sony 20 inch square colour display. Used to provide a multi-window working environment
- Metheus display driver.
- 3 Button Mouse
- HP 7000 processor.
- A simulation telecommunication system with headset, foot switch and panel-mounted push to talk facility.

The two measured sectors assessed during each simulation exercise each comprised Radar and Planning (Data) Controller CWPs. Each CWP provided access to the same ODID facilities and it was at the discretion of each individual controller to determine the display preferences.

Each CWP included a subjective workload panel (ISA) used by the controller for periodic input throughout the measured exercise. A configuration of video cameras was also in place for the measured exercises, providing both front and back images of the controller comportment.

Figure 2 : FAA ODID exercise in progress at the EEC

3.4.2 TRAFFIC AND AIRSPACE ADAPTATION

The simulated Washington ARTCC airspace comprised four sectors. The simulation airspace configuration paired adjacent Sectors 26 (Samson low) and 38 (Tar River high), and non-adjacent Sectors 27 (Liberty low) and 35 (Wilmington high). The simulation clock for the sectors started at 1800 UTC and measurements commenced at 1810 UTC.

The simulation studied a total of four organisations as follows :

Organisation A	Samson (26) and Tar River (38)	Baseline traffic
Organisation B	Liberty (27) and Wilmington (35)	Baseline traffic
Organisation C	Samson (26) and Tar River (38)	Added traffic
Organisation D	Liberty (27) and Wilmington (35)	Added traffic

The baseline traffic sample was based on Washington ARTCC System Analysis and Recording data and represented a 90th percentile day for the facility from September, 1992. The provision for Added Traffic exercises allowed for comparing use of ODID under a range of traffic volumes. An important characteristic of the two low altitude sectors was that both handled arrivals and departures for Raleigh-Durham International Airport.

In order to provide full System Assisted Co-ordination (SAC) and to facilitate the flow of traffic to and from the measured sectors, six feed sectors were created and staffed by three feed controllers. These feed sectors, employing full ODID technology, simulated the surrounding airspace including Atlanta and Jacksonville Centres as well as the underlying approach facilities.

The telecom panel realistically represented land lines between the measured sectors and the various en route and approach control facilities. Feed sector positions had individual telecom panels providing the land line link between measured and other feed sectors. Only one feed controller provided all approach control services for the two low altitude sectors.

Due to the fact that the ODID platform was designed to simulate the European air traffic control environment, several modifications to the US ATC operational procedures were required to be made.

The greatest part of these adaptations concerned the making and receiving of handoffs and in the concept of Transfer of Communications and Control. Within the US, FAA procedures prohibit controllers from allowing an aircraft under their control from entering an adjacent sector/facility until a handoff (either verbal or automated) has been offered to and accepted by the responsible controller in the adjacent airspace. If the required handoff has not been effected, a controller must issue vectors or holding instructions that keep the aircraft within the controller's own airspace.

US controllers use this handoff procedure as an initial traffic scan on entering aircraft and, if necessary, as an automatic means to regulate the flow of traffic into their airspace in cases of extreme traffic saturation.

European ATC procedures treat the flow of traffic between sectors/facilities in a different manner. The concepts of Transfer and Assume of ATC responsibility allow an aircraft to traverse airspace boundaries unless the receiving controller takes explicit action to inform the preceding controller to the contrary. The ODID system was designed to accommodate this European method of ATC.

Methods of adapting ODID to the US control techniques were explored but were found to be unworkable due to simulation pilot and feed controller workload or would have required extensive reworking of ODID software. Consequently, it was deemed necessary to adapt US handoff procedures to ODID technology.

The exact procedure for this adaptation was that the ODID and feed controllers began the process of Transfer of the label (datablock) at the point where they would normally have begun the automated handoff while simultaneously instructing the aircraft to transfer communications to the next sector. When the receiving controller was contacted by the aircraft, they Assumed control of the label. This indicated to the previous controller that communications transfer had been successfully completed. The critical difference between this procedure and US ATC operations is that calls were received from aircraft on which the controller may not yet have completed a traffic scan and which were thus not within their situation awareness. This lead to numerous instances where time was spent attempting to determine which aircraft were the source of initial transmissions. Additionally, it meant that the procedure whereby a US controller could stop the flow of traffic into their sector merely by not taking any handoffs was unavailable within the ODID environment.

This modified working methodology gave rise to a number of criticisms of the ODID system, most notably concerning the difficulty of advanced planning for aircraft inbound to the sector. The controllers unanimously agreed that any future US system based upon ODID principles must support the full PVD functionality associated with handoff procedures.

3.4.3 SIMULATION CONDUCT

The FAA ODID IV simulation study was successfully completed on 9 August 1996. A total of 44 simulation exercises were completed comprising :

Week 1	Controller training and system familiarisation	17 exercises
Week 2	Baseline measurements	16 exercises
Week 3	Added traffic levels	11 exercises

During the first week some flexibility was (necessarily) introduced into the exercise duration as it was important to ensure that all controllers had adequate practice with using the ODID technology in the simulated airspace. The decision to commence the baseline measurement exercises at the end of Week 1, although a simulation milestone, was made with the complete support of the participating controllers.

This offset reduced by one the number of time intervals over which ODID and PVD results could be compared for certain measures.

The reduced number of exercises in the third week followed a decision by the EEC and FAA Project Team to re-allocate more time to the debriefing of participants.

Over the course of the three weeks, the controllers also took part in evaluations during technology demonstrations of the EEC’s Highly Interactive Problem Solver (HIPS) conflict resolution and planning tool.

The high number of exercises achieved over the three week time span was possible due to excellent reliability of the simulation platform and the enthusiasm of the participating controllers. A typical daily schedule consisted of four exercises with parallel debriefings, HIPS demonstrations, and completion of questionnaires.

Controller rotation was balanced through the Radar and Data positions at each of four sectors. The rotation also included changing the groupings of controllers so that during the baseline exercises each controller was paired with all other controllers as many times as possible. This approach was repeated during the Added Traffic exercises.

EEC personnel staffing the three feed sector positions were two former military controllers and an engineer. The ten European ODID simulation pilot positions were staffed by seven licensed pilots, a former military controller, and staff having simulation pilot experience.

4. RESULTS CONCERNING THE ODID SYSTEM

For the participating controllers this simulation represented a significant departure from their normal working environment. A modified physical environment in terms of hardware and lighting was accompanied by the requirement to assess a new interface under operationally realistic conditions. The controllers were instructed to consider ODID as a technology concept demonstrator and that one of the objectives of the simulation was to assess how these concepts could be applicable to the FAA.

A number of comments were received which identified perceived functional shortcomings of the ODID system but which, in reality, were aspects that would be addressed in making the transition from a concept demonstrator to an operational system. The controllers also observed that the simulation did not address a pointout capability to an adjacent sector, those tasks requiring a keyboard, e.g., flight plan reroute, or the management of VFR flights. The technology described in this report would therefore require enhancement in order to provide such a level of performance.

For completeness, all of the questionnaire data and comments gathered during the simulation debriefing sessions have been integrated. In some cases, a distinction has been made between comments addressing the ODID concepts including its human-machine interface (HMI) principles and those addressing the current level of functionality.

4.1 CONSOLE / INTERFACE ENVIRONMENT

The ODID environment was based on separate CWPs for the Radar and Data controllers. When two controllers worked the same sector, each controller could make inputs on a flight at any time. The result of any new value input to the system was independent of the controller who initiated the action, but the effect of any data input in the radar label was displayed at both positions.

CWPs configured in the same sector were independent in terms of display management preferences. A request for information display was only displayed to the requesting controller's CWP.

4.1.1 CONTROLLER OPERATIONAL REVIEW

All controllers agreed that the integration of multiple display and input interfaces into a single display and input interface such as represented by ODID was a positive step for future ATC systems. All controllers agreed that ODID principles, i.e., the use of colour, conflict tools, and system assisted co-ordination, were an improvement for the Data (planner) position, and most felt the same for the Radar (executive) position.

(1) The orientation of the large SONY screen was considered important. Some discomfort was experienced by controllers early in the simulation and although invariably overcome, the simulation highlighted the need to provide a flexible environment (adjustable chairs, screen orientation) in order to accommodate the controller population. Some controllers felt the screen was placed too high, and raising the height of the chair seat did not always result in a comfortable position.

(2) The two ambient light levels used in the simulation room were deemed acceptable for simulation purposes.

(3) Text characters were at times considered difficult to read. Some character ambiguity was experienced and this was considered to largely arise from the thickness of the lines comprising the characters.

(4) At the sector level, the Radar and Data Controllers generally selected similar display preferences. The most notable difference was the practice of the Data Controller to display the radar window with a greater range. This was to accommodate the display of advanced planning information relating to sector inbound aircraft. The Data controllers also displayed more often the MTCA windows, which are described in a later section.

(5) The level of functionality provided by the ODID system evaluated by the controllers was such that it did not provide a number of data items or facilities currently available in the PVD. Specific examples cited included :

- Weather including the Data Controller Computer Readout Display (DCRD) outputs for altimeter readout and upper winds;
- Exception beacon codes;
- Brightness control groups.

4.2 THE MOUSE INPUT DEVICE

The ODID IV mouse had three buttons that were allocated as follows :

◊ Action Button	**AB**	(Left)
◊ Information Button	**IB**	(Middle)
◊ Window Management Button	**WMB**	(Right)

Button usage equated to either a single click or **P**ress and **H**old (**P&H**). The click implied a complete action, i.e., data input or information request, whilst the **P&H** provided a temporary viewing with the information disappearing when the button was released.

The **Action Button** was used to initiate system dialogue and to input new values into the system. It was used for all flight level modifications, route changes and clearances such as heading and speed.

The **Information Button** was used to display additional flight plan information either textually or graphically. The type of information display was contextually implied by the field selected, for example, IB on the radar label exit point (XPT) displayed the graphical route and on the callsign displayed flight plan. IB was also used to close an input window and when appropriate, to abandon an input sequence or to cancel a previously assigned restriction.

The **Window Management Button** was used for window management applications involving re-size, move, and swap (overlay priority). The ODID system provided the normal actions that one would associate with a 'Windows' environment.

4.2.1 CONTROLLER OPERATIONAL REVIEW

The controllers endorsed the mouse as a suitable input and pointing device although the need for a keyboard and notation capability remain. A number of control actions currently performed on the PVD were identified by the controllers as not lending themselves to a mouse input mechanism, e.g., flight plan reroute, change in destination or flight plan entry for a VFR pop-up. The following specific comments in relation to the mouse were made :

(1) Controllers found a difference in the ease of use of the two types of mouse employed during the simulation. The controllers identified that the mouse should provide a good ergonomic fit, feel 'solid' in the hand and should not provoke cramping after extended use.

(2) Some controllers considered the conventional mouse pad to be too small given the size of the SONY screen. Other types of surfaces for the work shelf top could be considered to remove the need for a pad.

(3) On occasions, considerable difficulty was experienced in accurately placing the cursor due to the presence of overlapping text and symbols. This was particularly acute in relation to the Radar Position Symbol (RPS). The ODID HMI is such that label deconfliction is performed from the RPS which should, therefore, take priority over all overlapping text on the display.

(4) A number of cursor attributes should be the subject of further prototyping study. These include cursor conspicuity, size and home position. With practice, the controllers were able to find and track movement of the cursor in a satisfactory manner.

(5) The input interaction within the sector controller team should be further investigated in order to better define the differences which may be created by a system such as ODID in roles and responsibilities of the Radar and Data Controllers. It was stressed that during busy situations, the Radar Controller workload could be reduced by allowing the Data Controller to perform display management tasks effecting the Radar Controller's displays such as label deconfliction. This would either mean the ability of the Data Controller to place the cursor on an adjacent screen or to allow the Radar Controller screen to be forced onto the Data Controller's display with subsequent inputs taking effect on both screens.

(6) The mouse button actions should be precise and require no special level of dexterity. The timing threshold for differentiating 'click' actions from 'Press and Hold' should be optimised to avoid frustration. This timing could be adjustable as a personal preference, for example, in a manner similar to which Windows environments on PCs allow a personal preference setting for click speed.

(7) Button allocations (AB, IB, WB) should be examined for use by left handed controllers. All eight controllers were right handed and used the mouse with their right hands. The controllers indicated there was some training effect in learning to differentiate the use of these 3 buttons. By the time when controllers were involved with the added traffic exercises most indicated they rarely experienced difficulty using the correct mouse button for different circumstances.

4.3 RADAR WINDOW

The radar window presented the controller with both radar and flight plan information (radar labels displayed radar track, mode C altitude and flight plan data).

Advanced flight plan information was presented to the controller in tabular displays called Sector Inbound Lists (SILs) whilst planning data was presented graphically. Planning tools and information windows could be superimposed on the radar window. An overlapping window was opaque to any stacked window below it.

The radar tracks (labels) superimposed in the radar window could contain up to five lines of data and were colour coded.

The radar window contained :

- ◊ slider bars at bottom and right hand sides for radar map off-centre function;
- ◊ a specialised button bar for radar window management, supplementary data display in the radar label, selection of Medium Term Conflict Assistance (MTCA) planning tools and window preference set-up selection.

4.3.1 CONTROLLER OPERATIONAL REVIEW

The following specific comments in relation to the radar window were made:

(1) The use of a slider bar to rapidly adjust the range zoom on the radar display was greatly appreciated. When the radar display was zoomed inward the space between text characters in the radar label should not increase in distance as was the case for this version of ODID display software.

(2) The facility for rapidly measuring the range and bearing between two selectable positions, e.g., aircraft to aircraft or distance from a beacon was considered a vast improvement compared to the PVD mechanism, with far fewer inputs being necessary.

4.4 THE BUTTON BAR

The button bar contained buttons used for setting up the radar window and selecting other tools and functions. The controller selected options according to personal preferences and as appropriate to the control function being provided.

Figure 3 :

4.4.1 Button Bar FUNCTIONS

- **Pre-Set Range Selection**

Each CWP was provided with three pre-set radar range settings.

- **Supplementary Radar Label Data**

Supplementary data provided a display in the radar label data block (permanent or a temporary quick look) of one of the following flight plan items: Departure airfield (DEP), Destination airfield (DEST), aircraft type (TYPE), Company name (COMP) and Next Sector (NS) frequency.

- **Radar Video Map Selector**

The radar video map selector provided the controller with a selection of video maps appropriate to the control position. Video maps were denoted by a text description on a button, e.g. Routes, Military. Selected values were indicated by a "depressed" button state.

The window remained open during map selection and had to be closed when video map selections had been completed.

- **Range and Bearing (R&B)**

The R&B function permitted the controller to measure the range and bearing between two controller selected points on the radar display.

- **Automatic Radar Label Anti-Overlap**

The radar label anti-overlap button selected or de-selected the system label deconfliction logic.

- **Manual Radar Label Position Selector**

A manual radar label position selection was available for all labels. Eight positions based on compass positions and related to the aircraft radar position symbol could be selected. Individual aircraft data blocks could also be manipulated through the position symbol for label direction and leader line length.

- **Radar Picture Range Change (Zoom Function)**

The radar picture range change function (slider bar) permitted the controller to change the range of the displayed radar image.

- **Lower and Upper Layer Filter**

This function permitted the controller to alter the upper and lower altitude filter settings outside of which grey unconcerned labels would not be displayed.

The function was accessed through a window comprising a central section with two slider buttons. The upper and lower filter layer values were displayed above the slider buttons.

- **Speed Vector Selection**

The speed vector button selected or de-selected a forward vector attached to the radar position symbol. The vector length was determined by the aircraft's ground speed. Discrete values between 0 and 10 minutes could be selected via small diamond shaped buttons.

- **MTCA Selection**

The Vertical Aid Window (VAW), Conflict And Risk Display (CARD) and Conflict Zoom Window (CZW) were tools provided to assist the controller in planning entry, exit and "through sector" conditions.

These tools were provided to both Radar and Data Controllers. Their use was left to the individual controller's discretion.

The buttons used to display these tools were toggle on/off switches.

- **Preference Set-Up**

This feature was designed to allow each controller to save their preferred window settings from one exercise to the next. The "saved" preference set was related to an individual CWP and controller.

Unfortunately due to a software constraint this feature was not available to the controllers during the simulation.

- **Move Function**

The move button allowed the controller to off-centre the radar image by specifying a ‘new radar image centre’ in conjunction with the mouse.

4.4.2 CONTROLLER OPERATIONAL REVIEW

The controllers endorsed the use of a button bar as a means of controlling individual display preferences and supplementary data display. They were unanimous that any future system should contain this type of facility. Specifically, the controllers made the following additional comments in relation to the button bar :

(1) The HMI of the button bar should be the subject of further study. Specifically, the button bar should be movable and even 'fragmentable' so that certain buttons can be placed at strategic points on the screen. Fragments of the Button Bar should be individually suppressible if their lower frequency of use does not warrant continuous display. A larger size for some buttons should be considered.

(2) Controllers were concerned that the cursor movement to the button bar resulted in reduced attention at the radar display. The speed vector should be a toggle where a second click on the same value would reset the vector length to a zero value so that the controller would not have to look back at the Button Bar and reposition the cursor.

(3) There should be a capability of an 'undo' type function, particularly given the fact that co-ordination can be effected by either member of the control team. One example cited was the need to 'take back' a handoff.

(4) The controllers noted that the 'global' application of certain functions from the button bar did not always meet their needs. For example, they would wish the ability to increase speed vector lengths on specified aircraft. It was noted that the selection of a large speed vector via the button bar caused confusion for in-trail aircraft. Other HMI techniques could be explored through prototyping that more closely emulate the action of a rotary knob, such as positioning the cursor on a button that increments the speed vector with each button click. This would reduce the need for the controller to constantly shift the focus of vision between the radar window and the button bar.

(5) The Button Bar does not need to display Company Name since that feature is infrequently used, Next Frequency which can be read off the radar label sector identification (SI) field, and radar label offset direction.

(6) The Button Bar could include the PVD system check override ("/OK") capability to reduce the frequency of use of a keyboard. This override permits a controller not having track control of an aircraft to change system data, for example entering a new Requested Flight Level.

(7) There was limited use of the automatic anti-label offset capability in the Button Bar in that once a particular radar label was manually offset it was no longer affected by use of the Button Bar function. The system needs to provide today's Host capability for offsetting labels through keyboard entry using the computer identification number (CID).

4.5 RADAR LABELS AND ASSOCIATED COLOUR STATES

The radar label in ODID is considered to be "dynamic" in that it changes shape as a consequence of the data input by the controller and the resulting system reaction. Planning and co-ordination states are indicated by colour changes in the label. These colour changes are due either to system generated events or controller input.

The radar label in the SA5 simulation consisted of :

- Data block (from two to five lines of data);
- Radar Position Symbol (filled circle);
- Leader Line connecting data block and radar position symbol;
- Speed vector of 0 to 10 minutes length;
- Trails (history dots/afterglow - 3 dots), and
- Climb and descent arrows.

Table 3 :

RADAR LABEL DE-CODE	
↓↑	Climb and Descent Arrows
AFL	Actual Flight Level (mode C) - CFL input when CFL not displayed
ahd	Assigned Heading
arc	Assigned rate of Climb/Descent
asp	Assigned Speed kts/M 2 digits
CALLSIGN	CALLSIGN in 7 characters
CFL	Cleared Flight Level (Planned Entry Level before assume)
COMP	Airline Company Name
DEPA	Departure Airfield
DEST	Destination Airfield
Freq.	Next Sector Frequency
NS	Current or Next Sector designator - showed only when advanced information
had	been passed
PS	Position Symbol - for ahd input
REL	Aircraft is Released (displayed until crossing sector boundary)
RFL	Requested Flight Level
sp.	Ground Speed (system monitored.) Input field for ASP when ASP not displayed
SSRC	Current SSR Code
tas	True Airspeed
Ti:me	ETA for sector exit crossing
Tn	First waypoint in NS ETA
Tx	Next waypoint ETA
TYPE	Type of Aircraft (ICAO)
w	Wake Turbulence Category
WPn	First Waypoint in the Next Sector
WPx	Next Waypoint on the flight plan
XFL	Exit Flight Level
XPT	Exit Point of the sector (airfield designator for lower and approach).

4.5.1 RADAR LABEL TYPES

- **Non Concerned**

line 1	**CALLSIGN NS**
line 2	**AFL**

No input actions are possible except calling down the extended label.

- **Concerned**

line 1	**CALLSIGN NS**
line 2	**AFL XPT**

No input actions are possible except calling down the extended label.

- **Standard Radar Label**

line 1	**CALLSIGN NS**
line 2	**AFL XPT sp** (asp input)
line 3	**CFL<down arrow symbol>XFL**
line 4	**ahd.asp.arc** (displayed following input)
line 5	***NS freq/REL/DEPA/DEST/TYPE/COMP***

The radar position symbol was used for opening the elastic vector for heading/direct route input or displaying the J-Ring. When a heading value was displayed in the label the elastic vector could be called from the ahd field. The XPT displayed the last two characters of the ICAO airfield designator for arrival traffic.

- **Extended Radar Label**

The extended radar label (ERL) provided all of the functionality of a standard label.

line 1	**CALLSIGN NS TYPE w tas RFL**
line 2	**AFL XPT sp Ti:me DEP DEST**
line 3	**CFL XFL WPx WPn**
line 4	**ahd.asp.arc Tx Tn**
line 5	**SSRC, REL, NS Freq, COMP**

4.5.2 MINIMUM LABEL DISPLAY

The number and content of lines displayed in a radar label data block indicated to the controller the sector Entry or Exit conditions to be achieved.

Lines one and two comprised the minimum radar label display. This usually indicated that apart from radar monitoring there were no outstanding transfer conditions to be achieved. This label typically applied to overflying traffic.

Line three information was only displayed when a constraint was input or a change in entry or exit conditions had been co-ordinated.

Minimum Information Rule

If one of the three altitude values (AFL, CFL and XFL) was different then line three was displayed, e.g., AFL < CFL, or CFL < XFL. Where two of these values were the same then only one of the values was displayed, e.g., only CFL displayed if CFL = XFL.

When AFL = CFL = XFL then only AFL was displayed - no line three.

Line four information was displayed when data had been input by the controller (for example, heading, speed restrictions). Line four data moved up to line three if no line three data was displayed.

Line 5 was used to display supplementary flight plan data or to indicate a co-ordination (for example, Hand-over or Release). This line moved up as for line four.

4.5.3 CONTROLLER OPERATIONAL REVIEW

The radar label format, content and the notion of 'Minimum Information Display' prompted the following comments from the controllers:

(1) The idea of minimum information was considered useful and controllers frequently used the displayed XFL as an indication of exit conditions still to be achieved. The dynamic shape of the radar label was indicated by the controllers to be a visual jogger aiding in assessing control intervention actions remaining on a flight.

(2) The controllers were unanimous in appreciating the ODID principle for access to supplementary information using the mouse button press and hold facility such as to temporarily display the ERL.

(3) The radar label was in some cases disconnected from the end of the leader line. This caused confusion in associating radar labels and position symbols.

(4) The controllers experienced frequent difficulty in offsetting radar labels over the course of the exercises. This primarily included difficulty in locating the RPS in order to commence the label move sequence and also having to wait for the radar display update to cycle in order to complete the offsetting entry. The overlap problem was increased when there was a fourth or fifth line shown in the radar label. The controllers sometimes temporarily separated labels by decreasing the range of the radar display.

A different approach for offsetting radar labels would be to grab the radar label rather than the RPS using a different mouse button. Another option would be to adjust the brightness of the RPS or certain radar label text to denote that the cursor was positioned over the object.

(5) Controller workload was increased due to the need to move data blocks, particularly in busy scenarios. Radar labels sometime moved, for example, in association with an aircraft turning resulting in a failed or erroneous attempt at data input.

(6) For departures, when the Radar Label first appears it should be displayed in a position where it does not overlap other labels for other departures.

(7) The potential for 'large' radar labels (5 lines) in ODID has served to highlight that any future system should closely address the means of label deconfliction.

The label content resulted in a number of comments. These comments merely indicated that many PVD facilities not replicated in the ODID system would indeed be required. Any future decisions regarding the HMI of the displays should consider therefore the integration of existing PVD data display facilities into the overall system architecture and design philosophy. During the baseline traffic exercises most controllers indicated that the information provided in the ODID radar label was more meaningful, although there was much more difficulty with offsetting the radar label during the added traffic exercises.

(8) There may be a need for the minimum radar label to display the CID. In some operational situations using the callsign is not sufficient such as for a flight arriving and immediately departing where the Host computer system would assign two CIDs for the same callsign.

(9) In the radar label the CFL could be repositioned to be adjacent to the Mode C AFL as found in the PVD data block. The label could display destination rather than next sector indicator.

An indication in the radar label would be needed if an aircraft had preferential (red) routing. The XPT could be shown in the ERL to be accessed when needed, as controllers tend to think of traffic flows based more on destination than XPT. The ERL may need to display a Remarks field in which can be displayed indications for the National Route Program or pilot preferred route, full route clearance, no radio (NORDO), celestial navigation (CELNAV), non-standard formation flight and aerial refuelling. The ERL should show an equipment suffix such as /A or /B.

There should be a provision to display an ERL for an aircraft that is in the system but not yet close to the sector by entering CID or callsign. The ERL route should reposition the departure and destination airport fields to be part of the route.

(10) Aircraft transitioning low and high altitude sectors should show an indication in the radar label so controllers are aware of the necessity to continue the climb/descent past the XFL. For example, controllers felt that Raleigh departures exiting at FL230 should have an arrow adjacent to the XFL to indicate that this is not their final requested level. Although this information is available in the ERL, the controllers felt that the indication in the radar label more suited their requirements.

(11) An indication is needed in the radar label for an aircraft that climbs into the sector, reaches its cruise altitude, and then descends all within the boundaries of the sector.

(12) The content of the ERL and the placement of the information will require further study with US controllers. The ERL could include equipment suffix (e.g., RNAV equipped), fix and time, filed airspeed, next sector, CID, and beacon code. The ERL does not need to look like the RL in terms of common fields. The ERL does not need to show CFL, AHD and ASP. The radar label needs to provide a scratchpad field capability analogous to annotating on the strips a series of speed changes issued to the pilot, and for co-ordination on the wrong altitude for direction of flight. Preplanned data should be uniquely coded. A separate colour could be used to denote wrong altitude for direction of flight. This data could be entered through a co-ordination popup window having an optional parameter that could also be clicked denoting that the information does not need to be co-ordinated.

(13) The provision is needed to simultaneously display ERLs for several aircraft such as when aircraft are holding.

(14) Future action needed for an aircraft could be indicated by highlighting the box around the radar label. This is analogous to canting the paper strip today in the strip bay.

(15) The system should inherit target and track symbology from the PVD where it has operational significance. The system should retain the PVD automatic handoff and inhibit automatic handoff capabilities.

The radar label should incorporate the destination as opposed to the sector exit point, or these two fields could time share depending upon the operational requirement.

(16) When an exception beacon code is shown in the radar label it should be displayed using an emphasis technique.

(17) Controllers were unanimous in their requirement for a full textual route display of an aircraft available on request using either the ERL or in a separate readout window. The route should start with the departure airport, include airways, and end with the destination airport. The ERL could truncate the route and the full route could be readout in a separate view analogous to the DCRD.

(18) The system needs to provide a conflict probe that can be used to check on a new or proposed route.

(19) The flight leg was appreciated by the controllers, in terms of ease of display and usefulness of information.

(20) Most controllers indicated that the elastic vector function to input assigned headings was useful.

4.5.4 PLANNING COLOUR STATES

There were four label colour states used in SA5. These are described below.

- **Not Concerned (Transferred)**

This colour was GREY. This state indicated that the controller was not "working" the flight (i.e., it is outside the sector), and that the aircraft had been transferred to another frequency.

- **Advanced Information State**

This colour was PINK and this state indicated that the sector had received the advanced warning information on the inbound flight and could commence entry condition negotiations if required. Advance information during the simulation exercises was received 10 minutes prior to sector entry.

- **Assumed**

This colour was WHITE and this state indicated that the aircraft was on frequency and that the controller had, or was, in the process of taking control of it.

- **Concerned State**

This colour was MUSTARD and this state indicated the continued need of the controller to maintain a situational awareness of this traffic. Mustard labels indicated traffic which had been skipped and which had not cleared the sector boundary or traffic that had been transferred but was still within the confines of the sector.

4.5.5 CO-ORDINATION COLOUR

The co-ordination colour was CO-ORDINATION PINK and it was applied whenever the item subject to co-ordination was displayed (message window, radar label, sector inbound list, etc.).

4.5.6 URGENCY/WARNING COLOURS

Two urgency colours were employed in the simulation to indicate abnormal situations to which the controller should pay attention. These were :

- **Short term Conflict Alert (STCA)**

RED - The STCA was used to indicate an imminent loss of radar separation based on a two minute warning. The STCA was not operational below 8000 ft. as an adapted system parameter.

- **Manual Warning Input**

YELLOW - The Data (planning) or Radar (executive) controller could click AB on a conflict number representing a system detected conflict or conflict risk which caused the callsign colour of the conflicting aircraft pair to turn yellow.

- **Alert**

YELLOW - Activated when an aircraft had been transferred to the next sector/controller before receiving clearance to its Exit Flight Level.

- **Planning Conflicts**

Planning conflicts were represented by colour in the MTCA windows.

These conflict colours were :

- Conflict	RED
- Risk of conflict	YELLOW
- Potential conflict	GREY

4.5.7 CONTROLLER OPERATIONAL REVIEW

The use of colour was naturally the subject of much discussion throughout the simulation. Whilst the controllers unanimously endorsed the ODID design principle of assigning colour to aircraft 'priority' status, i.e., the notion of 'Not Concerned' through 'Warning', discussions centred on the operational suitability of displaying given aircraft in a certain way within the framework of US Air Traffic Management. In general, controllers indicated that colour assisted them in executing ATC tasks. Most controllers agreed that the use of colours to represent airspace boundaries such as one's own airspace and special use airspace was understandable.

The discussions also extended to the appropriate brightness and relative intensity of certain items. The range of such comments merely highlight the requirement that any future system should be constructed with input from controllers and HMI experts.

- Pink labels :

(1) Controllers stated specifically that they were often unaware of the position of an aircraft at the first frequency contact as a result of the absence of the handoff facility.

(2) Some controllers indicated that there should be a fewer number of colours used to denote aircraft status, for example, to not differentiate pink and mustard states from white. Other controllers supported the current ODID implementation. Controllers supported the use of colour in such cases as using green for the Flight Leg with red to show the area of conflict in the Flight Leg.

- Mustard labels :

(3) The Mustard labels did not sufficiently attract the attention of some controllers during their visual traffic scan. For example, the controller could climb an aircraft and inadvertently not be aware of another aircraft because it was not white. It was recommended that the radar label remain white until the aircraft exits the sector. The indication that the aircraft is no longer on the frequency should be reflected in the next sector indicator changing colour (to mustard for example) or to possibly use an off white colour. This is equivalent to the PVD practice used by some controllers in zeroing the leader line as a memory jogger that the aircraft was no longer on frequency.

- Red labels (STCA) :

(4) The display of STCA information to the controller should be the subject of further study. Whilst some controllers considered the 'attention getting' capability of forced red callsigns to be sufficient, others felt that in addition, the J-Ring should be forced on for at least one member of the alert aircraft.

The controllers indicated that the RPS could turn red or yellow along with the leader line. The controller should be able to subsequently remove the J-ring and inhibit this function via a button bar function.

(5) Some controllers considered that the red callsigns were "fuzzy" and difficult to read. These comments serve to highlight the importance of text readability and in particular the degree to which various label colours will remain conspicuous on the chosen background. There were differences in brightness between the different Sony monitors, and EEC engineers noted that these monitors are frequently maintained due to colour shifts over time.

- Yellow warning :

(6) The controllers discussed the operational situation where an aircraft is transferred but has not yet been cleared to its XFL. The XFL was shown in yellow as a reminder to the controller. It should be possible to optionally click the IB on the XFL to remove the yellow coding.

- Grey labels :

(7) Typically, "minimum information" for the grey labels should consist of Mode C, callsign or if not available beacon code, together with RPS and history dots. The controller should have the facility to demand full label information. That is, it should be possible to get a full radar label on an aircraft having a grey label, just as with today's PVD where a full data block can be obtained from a limited data block.

(8) ERL and flight leg should be available for an aircraft having a grey label.

(9) The label should drop down to a minimum information label that is displayed after the aircraft exits the sector boundary, that is, the grey label should not be deleted.

(10) A number of controllers expressed the desire to be able to control, via a button bar function or personal preference, the display intensity of grey labels to be dimmer or brighter in appearance. Grey labels were not conspicuous enough for some controllers and were sometimes overlooked.

- **Brightness and intensity control**

(11) The controllers indicated that ODID should provide for today's PVD capability for brightness control that allows the brightness of different objects to be adjusted.

(12) The filled white dots representing trails were just slightly smaller but too similar to the dot representing the RPS. History trails or dots could be displayed using a different symbol (such as the slash used on the PVD today) to mitigate possible confusion with position symbols. The number of trail dots should be selectable in a manner similar to selecting the length of the speed vector. Trail dot brightness should be adjustable by the controller.

4.6 POP-UP VALUE WINDOWS AND CURSOR DEFAULTING

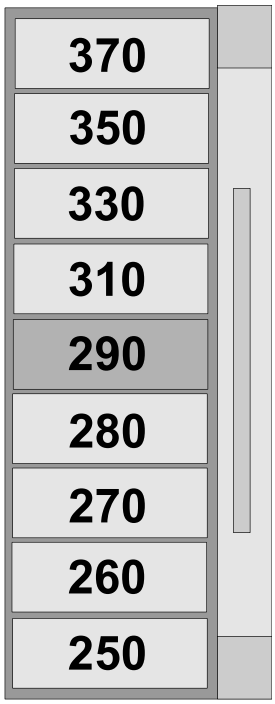
Data input in ODID was essential to ensure that the system was kept current on the controller's tactical planning. This provided for accurate conflict prediction (reflected in the MTCA tools), as well as System Assisted Co-ordination and the correct transfer of data between sectors.

Most data input in ODID was made via the use of pop-up menu windows. Most fields in the data label were contextually sensitive, that is to say, modification of a parameter could be effected through acting on that parameter in the radar label (or any other window where the data is displayed). For example, modification of a CFL could be effected through the CFL field in the radar label or a direct route could be effected through the sector exit beacon name.

4.6.1 CALLSIGN MENU WINDOW

The callsign menu window provided access to assume and transfer functions applicable to the silent transfer of ATC responsibility for a flight.

4.6.2 CFL/PEL INPUT WINDOW



This window contained nine flight levels/altitudes which were considered to be PEL values before assume of frequency, and CFL thereafter. A scroll bar permitted scrolling to new values. A full page and single increment up or down move function was also available.

The flight levels in the window were centred on the current XFL value. The range of levels was from FL 510 to FL 290 in increments of 2000 ft; from FL 290 to 6,000 ft in 1,000 ft increments.

Input on the PEL during the advance information planning state started a system assisted co-ordination.

4.6.3 XFL INPUT WINDOW

This window contained nine flight levels/altitudes with interaction identical to the CFL/PEL input window.

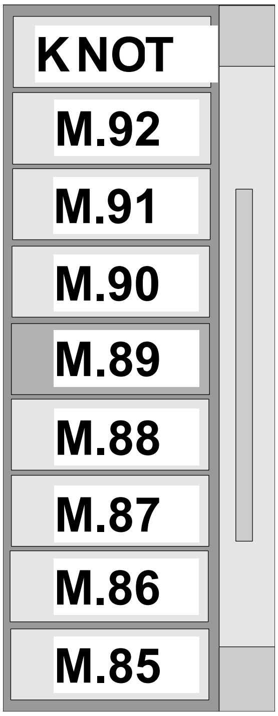
Input on the XFL during the advance information state started a system assisted co-ordination.

4.6.4 XPT INPUT WINDOW

This window contained the reporting points on the current flight plan, centred on the current exit point. A scroll bar permitted scrolling to new values. A full page and single increment up or down move function was also available.

Co-ordination could be generated through this window for direct routing following receipt of the advanced warning information.

4.6.5 asp INPUT WINDOW



The menu supported a choice of Mach and knots (IAS) and displayed nine values in descending order, top down. A scroll bar permitted scrolling to new values. A full page and single increment up or down move function was also available.

The default applied was Mach .78 for flights at or above FL 250 and 280 Knots for flights below FL 250.

Speed values in knots commenced at 12 (120 Kt.) and increased in 10 knot intervals to 40 (400 Kt.).

Speed values in Mach commenced at .68 and increase in increments of .01 to Mach .90.

Swapping between the Mach and Knots selection was achieved by clicking AB on the MACH/Knot text at the top of the window.

Co-ordination (receiving to offering sector) could be generated for assigned speed following receipt of the advanced warning information.

4.6.6 CURSOR DEFAULTING

Cursor defaulting was used in SA5 to logically anticipate the controllers' next input requirement.

When a default was applied the cursor would be positioned automatically on an input value when a pop-up window was opened. This default operation followed rules which were related to pre-defined controller preferences.

Default operations were applied in the simulation to the following input functions :

- **Callsign**

- on receipt of TRANSFER information	**ASSUME**
- after next sector advance information is sent	**TRANSFER**
- after assume (before next sector information is sent)	**FORCED ABI**
- on receipt of advance warning information	**SKIP**

- **CFL Input window**

- on the sector XFL (the controller was expected to give the best level);
- on the RFL if the RFL was below the sector XFL;

- **asp Input Window**

- MACH . 78 for aircraft at and above FL 250, and
- on 280 knots for aircraft below FL 250.

4.6.7 CONTROLLER OPERATIONAL REVIEW

The controllers strongly endorsed the use of input windows as a means of data input and agreed with the principle of cursor defaulting. Further HMI study is needed regarding the definition of pop-up windows. The implementation within ODID provoked some comment as described below :

(1) The page option was useful for quickly moving through the input window menu options / values.

(2) The text font and display size in the ODID pop-up windows was not considered optimal. Many problems with readability were experienced, in particular with altitude and speed input windows. The number of values presented in altitude input windows could be increased in order to reduce the need for scrolling. This may however be negated by an improved cursor defaulting scheme.

(3) Additional logic should be employed to determine the actual values displayed in input windows. For example, in altitude menu windows the 'levels of ownership' of the sector should be taken into account and also the current ATC profile. There is no need to display values lower than the AFL for climbing aircraft. The CFL menu window should immediately display values as far up and down as the airspace that is owned, with the provision to scroll to other altitude values.

(4) Input windows need to provide the capability to enter and display a speed that in ATC phraseology means greater or less than a specified speed, or an altitude at or above/below a specified altitude.

(5) The altitude input window should have a provision to pick "VFR" as a selectable option that changes the values in a manner similar to the speed input window.

(6) The SA5 Exit Point input window did not accommodate aircraft being placed on direct routes to points defined by their latitude and longitude co-ordinates.

4.7 SECTOR INBOUND INFORMATION

In the ODID system, advanced information was displayed to a sector 10 minutes prior to the estimated entry of the flight in a Sector Inbound List (SIL). The displayed data was obtained from the information sent by the preceding sector.

The SIL windows were displayed in all sectors. They provided the controller with the first advance warning information for planning purposes.

SILs could be geographically dispersed according to their pre-defined sector entry areas, although the controller could reposition these windows according to personal preference.

- **SIL Flight Allocation**

For the SA5 simulation, aircraft inbound to a sector were allocated to a sector inbound list (SIL) according to their sector boundary crossing point. Designated tracts of sector boundary were linked to selected SILs. This procedure ensured that aircraft on direct routes were displayed in a SIL relevant to the geographical area of the sector that they crossed. Departing traffic was allocated to a specific DEPARTURE SIL.

At the feed sector positions traffic was presented in a Navigation Start SIL ten minutes before commencing navigation. Traffic entering a feed sector from a measured sector was posted in a single SIL.

- **Activation**

- Information displayed	10 minutes prior to planned sector entry.
- Information removed	following assume by the receiving sector controller.
- Information up-dated	following system detected deviation or co-ordination.

- **Content**

Each SIL was defined by a beacon name in the window header. The contents included :

- Sector entry time;
- callsign (maximum of ten callsigns displayed; scroll bar permits scrolling to additional callsigns);
- PEL;
- XPT, and
- <check mark symbol> (when the entry and exit conditions have been checked by the controller).

The data made available to the next sector included the planned XFL of the current sector (as the PEL of the next sector), together with any speed, heading or rate of change (climb or descent rate) inputs which had been made on the flight by the current sector.

Any subsequent changes of XFL (after transmission of the advance warning information) were co-ordinated with the next Centre/sector via the System Assisted Co-ordination function.

4.7.1 CONTROLLER OPERATIONAL REVIEW

(1) The display of sector inbound data in the SIL ten minutes prior to sector entry was considered too short for planning purposes. In the US, controllers can have strip information up to 30 minutes in advance of sector entry which can be particularly useful for verifying the integrity of an aircraft route.

(2) A future system should incorporate ‘extended SILs’ which the controller can display on request for aircraft inbound to the sector in typically the next 30 or more minutes (up to the maximum time the Host computer system can print strips). A slider bar could be provided to vary posting time, with independent selections for the Radar and Data controllers to accommodate different operational needs. For example, the Radar Controller may prefer to have aircraft entered into the SIL 10 minutes prior to entry to the sector, whereas the Data controller may want 30 minutes. The Data Controller may also want only a single extended SIL to use, such as to review routes. The Data controller may make more frequent use of the SIL and CARD at lower traffic levels and then shift to more tactical involvement when traffic increases.

(3) The number of SILs depends upon the complexity of the airspace. The system should be adaptable regarding the number of SILs that a sector would have. A SIL could be sub-divided in the manner that strips are posted under different headers.

(4) The sorting criteria (time, entry point, destination, XPT, callsign, altitude, etc.) should be user selectable based on any field that is displayed in the SIL.

(5) The controllers considered that when the flight leg is accessed through the SIL, the direction of flight through the sector should be displayed if the position symbol and radar label are not yet displayed on the screen. Additionally, the call sign could be shown adjacent to the Flight Leg.

(6) Further study is needed regarding whether the SIL should be transparent if it is positioned on the radar display. There was concern that an opaque SIL could obscure a popup aircraft. The controllers indicated that most windows should not be transparent.

(7) Aircraft climbing into the sector should have an “up” arrow such as in conjunction with the XFL and RFL. An indication is needed when a departure has an RFL higher than the XFL.

(8) It should be possible to move a posting from one SIL to another SIL in the sector, and to force an entry to a SIL in another sector.

(9) The controller needs to be able to access flight information (route, PEL, XFL, etc.) and effect backward co-ordination for aircraft not yet posted in the SIL. This could be provided through a capability to force a call sign into the SIL such as using the Force ABI capability. This could be used for aircraft seen through quick look of the adjacent sector, for example co-ordination concerning wrong altitude for the direction of flight. Backward co-ordination would allow the controller to send a message to the upstream sector that has track control but before that aircraft is posted to the SIL.

(10) The separate SIL for a departure airport should include information for departures such as time and route, as well as display of preferential or red routing. SILs could also be provided for destination airports. Access to either the full or truncated route should be available through the SIL.

4.8 SYSTEM ASSISTED CO-ORDINATION AND DATA TRANSFER

The principle of data exchange was to provide the most recent information to the adjacent control Centre/sector and to reduce to a minimum the need for telephone calls.

Advanced information was received by the next downstream sector ten minutes prior to sector exit from the current sector or coincident with a “Forced ABI” input by the current sector. The current sector controller was advised of this data "transmission" by a change of sector identity in the radar label.

Co-ordination of sector entry and exit level changes, heading, direct route and speed restrictions resulting from manual inputs were carried out silently via a system assisted message exchange.

4.8.1 CO-ORDINATION MESSAGE WINDOW

The “on-screen" System Assisted Co-ordination (SAC) provided inter Centre/sector co-ordination using pre-defined messages for entry and exit levels, heading, direct route, speed and rate of climb/descent restrictions.

Two message windows were used, MESSAGE IN and MESSAGE OUT. The parameter being co-ordinated was presented in co-ordination pink in both the radar label and message window as a means of gaining the attention of the controller. A co-ordination was accepted either by clicking on the appropriate field of the message posted in the MESSAGE IN window or wherever that "field" was displayed

Acceptance of co-ordination removed the current messages in the concerned sectors IN and OUT message windows and the new value replaced the original value in the radar label.

If a proposal was not acceptable to the controller, a counter proposal could be initiated. The new "counter proposal" value (current or some other value) was reflected in the message In and Out windows as appropriate. There were no system limitations to counter proposals. Controllers were free to determine at which stage they should enter into telephone co-ordination.

4.8.2 CONTROLLER OPERATIONAL REVIEW

The controllers considered the SAC facility to be the single most useful benefit offered by the ODID system. They were unanimous in finding SAC to be an improvement over the method of co-ordination used in the PVD/M1 environment.

(1) The controllers felt that received messages quickly received attention. The use of a co-ordination colour was endorsed by the controllers. This colour offered the additional advantage that the Radar controller was able to see the co-ordination messages being generated by the Data controller.

(2) The System Assisted Co-ordination proved particularly useful in Sector 27 (Liberty) where arrival sequencing often required co-ordination with the adjacent centres of Atlanta and Jacksonville. The ability to issue direct route, altitude and particularly speed requests was appreciated by the controllers.

(3) The controllers considered that a future system should provide assisted co-ordination to allow an aircraft to be pointed out to another sector.

(4) The controllers highlighted the need to be able to hand-off an aircraft to a sector other than the next sector as identified by the automation. The controller should be able to select the sector to which the aircraft is to be handed off to such as through a popup window.

(5) To deny a requested change in ODID the controller had to enter a counter proposal using the original current value. An unable function would be needed to convey that a change is not approved.

(6) When the controller co-ordinates with the upstream sector for a new higher PEL, there should be some means for the CFL to be updated with the new PEL rather than having to re-enter the new CFL value.

(7) The system should provide an Unsuccessful Transmission Message (UTM) as shown on paper strips today to indicate when data have not been passed to the next facility.

4.9 MEDIUM TERM CONFLICT ASSISTANCE - MTCA

4.9.1 TRAJECTORY CALCULATION

The MTCA tools used a system determined trajectory for conflict prediction. An initial trajectory was calculated for each aircraft and subsequently re-calculated following controller input or track deviation.

Trajectory calculation was used to create a sector sequence for data flow and to provide aircraft trajectories for MTCA conflict prediction.

This provided :

- transmission of system detected events (e.g. conflict information, label colour planning states etc.);
- transmission of advance warning information between sectors;
- system supported co-ordination.

The process of trajectory calculation commenced with an initial trajectory calculated ten minutes before an aircraft started navigation. This generated the initial advance warning information to a sector and provided the controller with initial planning information.

The trajectory calculation took into account the ATC operational environment which included:

- the aircraft type and associated performance;
- the flight plan route ;
- the requested flight level (RFL) in the flight plan;
- any pre-defined sector restrictions (ATC constraints, e.g., sector XFLs etc.) explained in letters of agreement or local operating instructions.

When calculating a climb trajectory the system attempted to attain the aircraft's RFL as quickly as possible. Attaining the RFL was only interrupted by ATC constraints which restricted the trajectory evolution.

When calculating a descent trajectory the system attempted to attain the constraint level as late as possible. The initial aircraft trajectory could be modified by controller inputs resulting in a trajectory re-calculation including :

- direct route input;
- PEL or XFL input (or co-ordination acceptance of these values).

The re-calculation of an XFL on a vertical sector boundary was carried into the next sector as that sector's entry level or PEL. Thereafter the trajectory was governed by trajectory calculation rules relating to the RFL and ATC constraints.

In the case of a direct route input, the system calculated the aircraft's track to the new point and then the track to the first reporting point in the next sector. From that position the aircraft flight plan route was maintained.

4.9.2 CONFLICT TYPES

Medium Term Conflict Assistance (MTCA) rules were defined to predict three levels of conflict and to provide for their display and interrogation by the controller. The horizontal flight path included the airspace 8 nautical miles either side of the subject aircraft's track.

The conflict types defined for this simulation were as follows :

- **CONFLICT**

A conflict was the prediction that an aircraft (or several aircraft) would be detected on the subject aircraft's trajectory, within its AFL to XFL level band and that their vertical trajectories were calculated to cross within the 8 nm flight path.

- **CONFLICT RISK**

A conflict risk was the prediction that an aircraft (or several aircraft) would be detected on the subject aircraft's flight path, within its CFL to XFL level band but that their vertical trajectories were not calculated to cross.

- **POTENTIAL**

A potential conflict was the prediction that an aircraft (or several aircraft) would be detected in the subject aircraft's horizontal flight path outside its AFL to XFL level band.

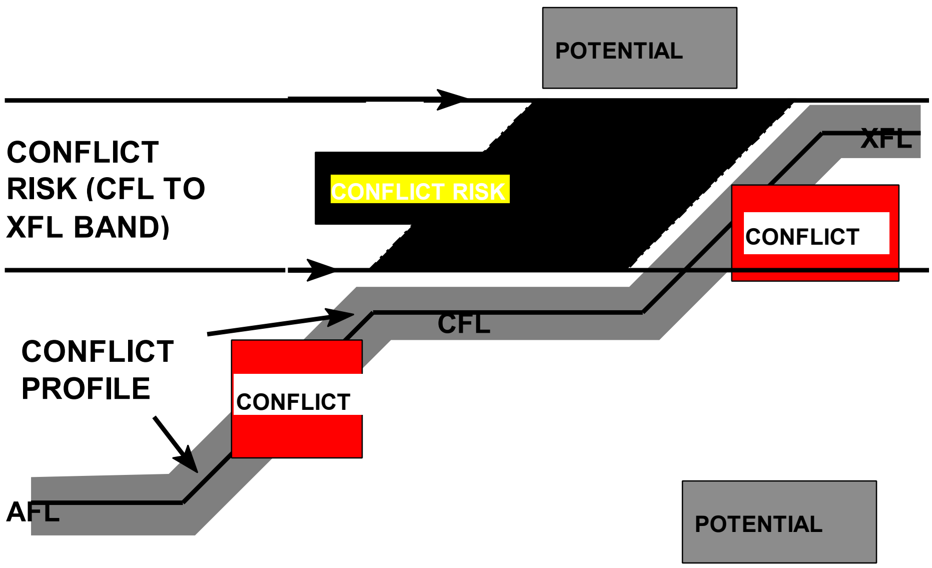


Figure 4 : Conflict representation in ODID

Conflict types were displayed in MTCA windows as colour coded blocks according to conflict classification. This provided assistance to the controller in planning an aircraft's entry, through sector and exit conditions.

The prediction of conflicts, conflict risks and potential conflicts was applied for the whole length of the aircraft's flight path through a sector from three minutes prior to sector entry until three minutes after exit.

4.10 MTCA WINDOWS

The MTCA windows provided graphic images in plan and vertical views which were based on current flight plan data and updated by controller and system monitored track deviation. The windows displayed conflict, conflict risk and potential conflict information for planning purposes.

MTCA windows could be temporarily or permanently displayed depending on the selection of the window via the button bar or through press and hold action on the PEL / XFL fields in the data block.

Dialogue was standard in all MTCA windows for the designated target in accordance with the dialogue functions available on the same fields in the radar label.

There was only a single occurrence of each window open at any given time and window display was selectable (on/off) through the button bar.

4.10.1 CONTROLLER OPERATIONAL REVIEW

(1) There was concern that the MTCA tools rely on flight plan information which may lead to a loss of confidence in their usefulness compared to radar data. The VAW and other tools would be more useful if track information was used.

(2) The current implementation of ODID renders the MTCA tools as being most suitable for strategic deconfliction within one's own sector.

4.10.2 CONFLICT AND RISK DISPLAY - CARD

The CARD provided the controller with advance warning of conflict and conflict risk situations in both graphic and text formats. Both Radar and Data Controller were provided with a CARD window. The intent of the CARD was to facilitate controller priorities for recognising and assessing potential conflict situations.

A conflict (or risk) was represented by a horizontal line drawn along the expected minimum distance which was indicated on the Y axis (minimum distance). The left point of the line indicated the start of the conflict (with reference to the X axis of time) and the right point its minimum separation time.

The CARD was updated dynamically. Hence, the conflict line moved from right to left as the time remaining until predicted loss of separation counted down.

The window was pre-set for conflict and risk display. Risks could be de-selected by clicking on the RISK button in the window. Conflict lines were coloured red and risk of conflict was yellow.

The controller could change the graphic display parameters (time and distance) by a press and hold mouse action on the Zoom button in the window.

4.10.2.1 CONTROLLER OPERATIONAL REVIEW

(1) Some concern was expressed about the usability of the CARD for departures and arrivals to the same airport in lower altitude airspace. The layout of the CARD did not provide for intuitive use by the controller. Pairs of aircraft climbing from approach control airspace should be inhibited from being shown in conflict with each other in the CARD, as should pairs of inbounds. There were too many false alarms for departures and arrivals. It would be more useful, for example, to show alerts between departing aircraft and overflights for sequencing. Conflicts should be filtered out for aircraft flying SIDs and STARs, as in the case of departing aircraft on diverging headings. However, the CARD should filter in conflicts involving overtake situations where there are different aircraft types involved.

(2) Additionally, the controllers would have wished a means of deleting alerts from the CARD once they have been determined as requiring only radar monitoring. In addition, a tickmark facility in the CARD should be available once an alert had been verified in the CZW.

(3) Some controllers stated that they did not allocate priorities based on display information in the CARD. An alternative would be to sort by aircraft, i.e., show all alerts pertinent to a particular aircraft in order to better identify the relevant intervention.

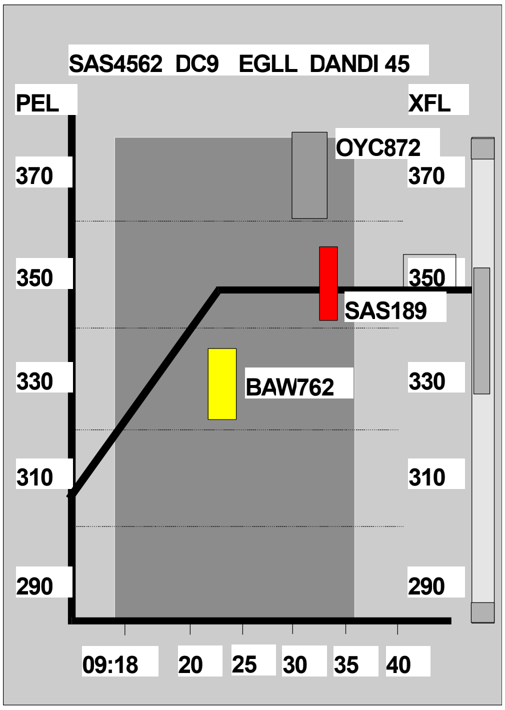
(4) It was noted that the Data controller may have a reduced situation awareness as a result of monitoring the MTCA tools and having a reduced radar display. The time and distance information was understood but rarely used. The Flight Leg was quicker to use to assess conflicts compared to the CARD and with a listing of conflicts might be sufficient compared to the CARD.

(5) The CARD was found to not be intuitive in providing information that can be quickly understood. Analysing information in the CARD takes too much time, and controllers used the CARD only as time allowed. Controllers rarely or never identified conflict resolutions with the aid of the CARD. The CARD seemed to have limited usefulness in helping the controller to set priorities with MTCA alerts.

4.10.3 VERTICAL AID WINDOW - VAW

This window provided the controller with an opportunity to verify pre-entry, in-sector and sector exit conditions. It was also possible to commence sector entry or exit level co-ordination through the window.

Figure 5 : Aircraft profile in the VAW



The VAW displayed a vertical view showing the flight plan route and through the sector. The flight profile was a single line. Aircraft in "conflict" with the subject aircraft were presented as colour coded blocks of airspace.

A conflict number and conflicting aircraft callsign were positioned beside the block. The cross section of the conflict "block" indicated either crossing (square shape) or "in trail" conflict types (extended block) or opposite direction (narrow aspect).

A scroll bar (right side of the window) permitted scrolling to new levels. A full page and single increment up or down move function was also available.

The graphic image was updated for the subject aircraft following a trajectory recalculation for that aircraft.

When re-sized (larger) additional flight levels were displayed. An initial nine levels were presented on first opening with the window graphic centred on the CFL.

The displayed PEL and XFL values provided CFL/PEL and XFL input possibility. The subject aircraft's flight planned RFL was indicated by a box surrounding the appropriate level in the XFL value display.

The VAW could be independently displayed by either or both the Radar and Data Controllers. ODID provided for display of the VAW for either inbound aircraft having a pink radar label or aircraft that were under track control of the sector having a white label.

4.10.3.1 CONTROLLER OPERATIONAL REVIEW

The following comments were made by controllers regarding the VAW.

(1) The VAW was considered useful as a planning tool and in the identification of potential conflicts as requiring planning or radar solutions. The controllers used the VAW for most inbound traffic. The VAW was less useful once the aircraft had entered the sector due to the tactical nature of the operation.

(2) The VAW is considered potentially very useful in upper sectors, but needs refinement for use in low altitude sectors adjacent to or above approach control airspace. The need for filtering of aircraft in low altitude airspace prior to display in the CARD also applies to the VAW as the controllers found the large blocks of red distracting and of little use. The VAW needs to show all traffic at higher and lower altitudes including traffic going in opposite directions so that the controller can check whether changing an aircraft altitude to another level is feasible.

(3) Some controllers generated SAC messages for PEL/XFL conditions directly from the VAW during the added traffic exercises after this functionality was further explained.

(4) The VAW was used to verify the possibility for conflict of an aircraft at sector entry and exit. The presence of red blocks merely alerted the controller to monitor the situation, particularly in lower airspace where many of the alerts were not considered genuine. The VAW was used to understand the conflict and where appropriate derive solutions.

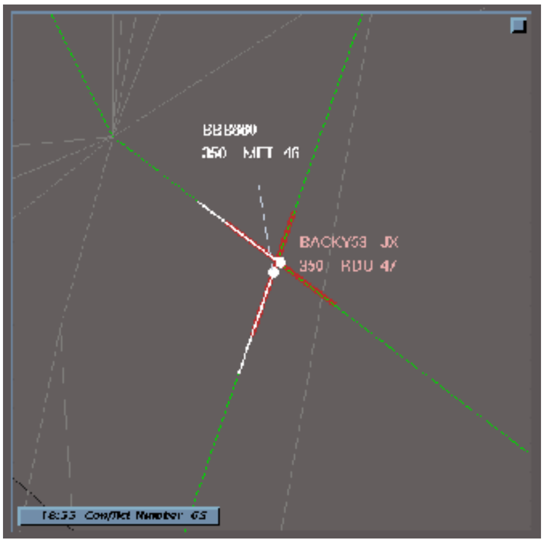
(5) The controllers appreciated the 'tickmark' facility in the SIL once conflict information had been verified in the VAW. Most controllers indicated they made frequent use of this checkmark feature during the baseline and added traffic exercises.

(6) The VAW would be more useful in lower altitude sectors if it was updated for changes in altitude made by the controller at any point in the sector. If an aircraft was descended early the VAW did not show conflicts for that trajectory.

(7) The algorithms used with the VAW should be modified to use track data to provide accurate information. The use of red should reflect accurate predictions to maintain the controller's trust.

4.10.4 CONFLICT ZOOM WINDOW - CZW

Figure 6 : ODID Conflict Zoom Window



The CZW provided the controller with an opportunity to verify the nature of a conflict (e.g. crossing ahead, behind etc.). The window displayed 20 nautical miles of airspace around the predicted minimum distance point of the conflict. Conflicting traffic was displayed at their predicted positions with standard radar label information.

The time of the predicted conflict and the conflict number were presented at the bottom left corner of the window.

Conflict information (conflict or conflict risk) was described as flight legs defining conflicting tracks. This gave the controller an indication as to whether the situation was crossing, converging or in trail.

4.10.4.1 CONTROLLER OPERATIONAL REVIEW

(1) Overall, the CZW had limited use by the controllers. Their conflict resolution strategies were rarely or never different as a result of the availability of the CZW.

(2) The CZW needs to be dynamic, not static in showing conflicting flight legs. The CZW should show other aircraft in the area to see what other altitudes are taken and not available for use to resolve the conflict.

(3) Controllers considered that the CZW should be used on a quick-look basis rather than permanently displayed. It was felt that in certain situations the CZW could be misleading due to the fact that it is not dynamically updated. The CZW would need to provide more flight plan information for the controller to determine a resolution to the conflict. The controller could resolve the conflict in the CZW but there is not enough information provided about how that resolution would effect other flights.

(4) The Flight Leg in the CZW should indicate where the conflict will occur in the sector, when it is predicted to occur, and how far away it is from the present positions of the aircraft involved.

(5) The absence of automatic label deconfliction in the CZW proved frustrating for the controllers, and on occasions the direction of flight was difficult to determine.

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5. BASELINE COMPARISONS

The SA5 simulation was performed with the aim of replicating, where technically applicable and operationally meaningful, the analysis presented in Reference 3. In order to achieve this objective, the conduct of the SA5 simulation aimed to align itself as closely as possible to that of the PVD baseline simulation. This included adapting the Washington Centre airspace configuration used in the PVD baseline simulation into the Operational Display System and generating ODID traffic samples using the PVD baseline scenario flight plans. Eight ODID exercises were completed using the baseline traffic for sectors 26 and 38 and another eight for the sectors 27 and 35 configuration. The data reduction for SA5 involved analysis using measures associated with five operational constructs specified in the baseline measurement methodology. These constructs consisted of Capacity, Safety, Task Performance, Workload and Usability.

The PVD baseline was not developed in anticipation of SA5. The replication of the PVD baseline simulation analysis was, however, limited in SA5 within a number of domains.

- **Measurement time intervals**

The discovery during the analysis phase of the SA5 simulation of the incorrect specification of the PVD data collection time interval showed that the ODID exercises were stopped earlier than was required to provide directly comparable data sets. The ODID data reduction and analysis were repeated so that data having common time intervals could be analysed. The ODID measurement data collection time interval was 50 minutes for Sectors 26 and 38, and 80 minutes for Sectors 27 and 35 to accommodate a ten minute offset used in the PVD data collection time interval.

Within the PVD measures, the offset could at least be partially compensated for in those cases where time interval data was reported or available. With one exception involving the measure associated with offsetting data blocks, all baseline comparisons used PVD data that were based on 60 and 90 minute measurement periods for sector configurations 26/38 and 27/35, respectively. PVD time interval data for most measures used in this study were not available with which to filter out the data collected in later time intervals. Inclusion of these data from the later time intervals had an unknown effect on the PVD data.

- **Absolute traffic counts**

Examination of PVD sector traffic counts showed a disparity between the data provided in Reference 3 and traffic sample flight plan information. The basis for the PVD measure of Aircraft Under Control was not specified in Reference 3. In ODID, Aircraft Under Control was based on the number of aircraft on a sector frequency during the measurement period. By considering all flights having navigation start times falling before the end of the measurement period, it was possible to recalibrate the PVD traffic counts in order to provide a more objective and accurate comparison to ODID. It is possible, even likely, that this method of recalibration for the PVD will overestimate the actual figure.

In order to compensate for the differences in traffic counts between PVD and ODID and to reduce the effect of differences in measurement time periods, measures were derived as ratios of traffic counts. Derived PVD measures which were expressed as a ratio to traffic count may, therefore, be smaller than reality.

The overall PVD recalibrated average traffic count for the 4 sectors was 185.0 aircraft and the ODID average traffic count was 161.9 aircraft. The ODID traffic count for the added traffic exercises was 234.0 aircraft, or 144% above the ODID baseline traffic count.

The average traffic counts at the sector level are shown in the following table. The table also shows the percentage increase in added traffic above the ODID baseline traffic level.

Table 4 :

	Sector 26	Sector 27	Sector 35	Sector 38
PVD - Recalibrated	40	47	69	29
ODID Baseline Traffic	33.7	39.1	58.4	30.7
ODID Added Traffic	55.3 64%	51.5 32%	82.5 41%	44.7 46%

The differences between the PVD recalibrated and ODID baseline traffic counts for Sectors 26 and 35 cannot be readily accounted for. There is some basis for understanding the difference between the counts for Sector 27. During data reduction, it was discovered that 10 aircraft that had been present in the PVD simulations had been omitted from Sector 27 of the ODID simulations. These aircraft included 9 USAir departures from Charlotte airport which transit Sector 27 from Atlanta Centre to Sector 36, climbing to FL230. One more aircraft, an American Airlines flight inbound to Raleigh airport near the end of the simulation run was also omitted.

It is likely that during the ODID simulation preparation phase that the nine Charlotte departures were omitted from the traffic sample since the simulator-determined flight profile was based on accurate climb rates which would place these aircraft above sector 27 airspace prior to their crossing the sector lateral boundary. This sometimes happens in the live Washington Centre environment, however procedures and lower than optimum climb rates usually ensure that the aircraft are worked by the Sector 27.

The operational significance of these Charlotte departures is that several, but not all, of the flights would have been in possible confliction with high level overflights transiting the sector in north or southbound directions. This would probably have caused the Sector 27 controllers to use ODID System Assisted Co-ordination (SAC) capabilities to co-ordinate higher altitudes for several of the omitted flights in order to continue their climbs and top the traffic. For those flights that were not in confliction with any Sector 27 traffic, it is likely that the controllers would have used the ODID “skip” feature and not be required to communicate with the aircraft.

For the Raleigh airport inbound near the end of the simulation, the navigation start time was just seven minutes before the projected end of the simulation. It is probable that the simulation preparation software omitted the flight because it projected that the aircraft would not cross the sector boundary before the end of the exercise.

The traffic counts in the above table for added traffic were based on three exercises for sector configurations 26/38, and two exercises for 27/35. The remaining six exercises for added traffic exercises involved other variations of the baseline traffic samples and results from those exercises were not used in this report.

- PVD simulation documentation

There are three apparently inconsistent and incompletely defined altitude-related PVD data sets quoted in Reference 3 involving simulation pilot altitude message inputs, controller interim and assigned altitude PVD message inputs, and assigned altitude. This is further addressed in Section 5.1.2.

5.1 CAPACITY

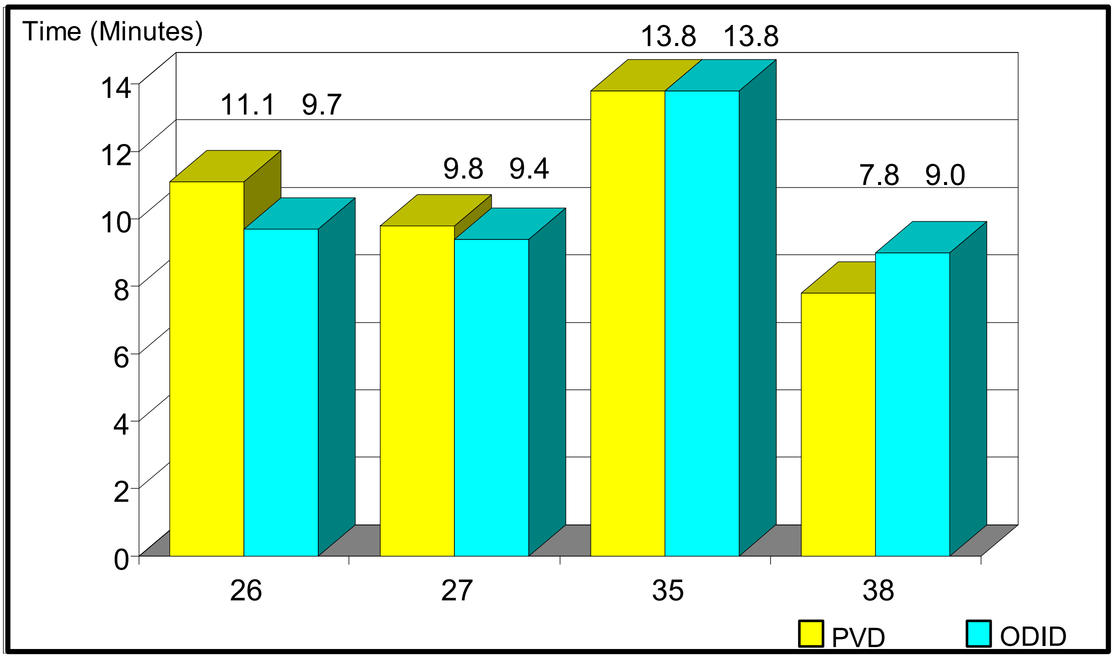
The Capacity operational construct was defined in Reference 3 as a measure of traffic through a specific section of airspace during a specified time period. Capacity may change as a function of controller, pilot, or system variables. SA5 used two measures to provide information about Capacity: Average Time in Sector and Altitude Changes Per Aircraft.

5.1.1 AVERAGE TIME IN SECTOR

Average Time in Sector was a measure used in Reference 3. Variations in Average Time in Sector may indicate how different en route ATC systems effect the expeditious flow of air traffic.

The baseline comparison at the sector level of average flight time (minutes) is shown in the following figure.

Figure 7 :



Aircraft showed less time in sector with ODID for the low altitude sectors. In Sectors 35 and 38 it is possible that the PVD controllers experienced with this airspace shortened the flight distance by clearing flights direct. The ODID controllers may have had flights stay on those routes due to limitations in the number and geographic location of fixes with which to clear aircraft direct. In addition, from one exercise to the next ODID flight times showed smaller variation about the average times compared to the PVD baseline, indicating somewhat more consistent movement of aircraft through all four sectors (statistical standard deviations for PVD ranged from 0.65 to 1.77, and for ODID from 0.41 to 0.79). However, there was a greater number of repetitions of ODID exercises compared to the PVD baseline and this may have resulted in a more stable data sample. This reduced flight time with ODID is related to controllers use of SAC, as described in Section 6.

5.1.2 ALTITUDE CHANGES PER AIRCRAFT

Altitude Changes Per Aircraft was derived for this study as the ratio of total altitude changes to the number of aircraft under control. It was defined as an indicator of sector efficiency relative to vertical movement of aircraft through the airspace.

In order to compare the numbers of altitude changes per aircraft, it was decided to use different sources of information in the ODID and PVD systems. Operational characteristics of the two systems contributed to this decision.

In the PVD simulations, the method of DYSIM pilot input can result in multiple inputs to accomplish a single task. This is due to several reasons. Firstly, due to lack of DYSIM positive feedback regarding operator entry, specific actions are sometimes repeated to ensure that the necessary input is accepted. Secondly, even though controllers used as pilots may have had recent experience with DYSIM, their level of proficiency was necessarily lower than on the live PVD system. This could have contributed to increased errors and a higher tendency to repeat control inputs. PVD controller altitude message inputs should not be subject to such duplicate entries.

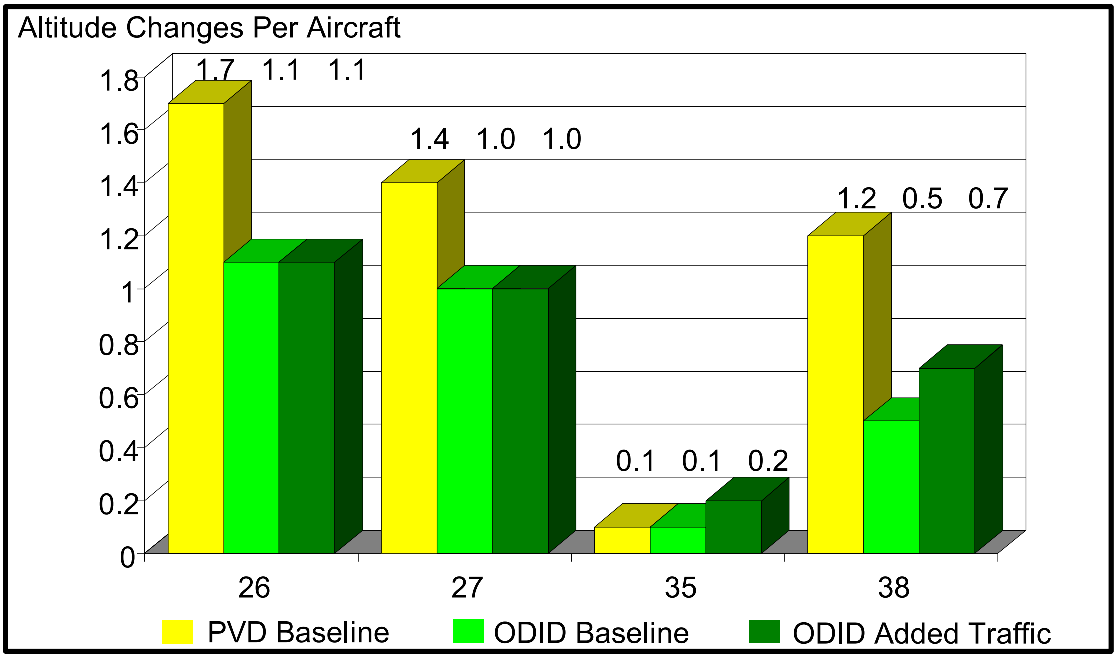
In the ODID simulations, the entry of a new CFL by the measured controllers did not always correlate to an actual altitude assignment to the aircraft. This is due to the fact that if the CFL and the XFL were the same value, the ODID label does not display the XFL. In this situation, if the ODID controller wished to access the XFL, one method to do this was to enter a new CFL that was not subsequently issued to the aircraft. This prompted the display of the XFL, which the controller could then access. This method was used by some of the ODID controllers. Due to a more advanced simulation pilot interface, the ODID simulation pilots were much more likely to enter only one altitude change when an altitude clearance was issued to the aircraft.

For the above reasons, it was decided that the most accurate comparison for Altitude Changes Per Aircraft was derived using PVD Radar and Data Controller inputs and ODID simulation pilot entries.

The PVD data were based on controller entries of interim altitude (QQ) and assigned altitude (QZ) messages. The ODID data were based on simulation pilot altitude entries.

The baseline comparison for the number of altitude changes per aircraft, as well as the ratio during the ODID added traffic exercises, is shown in the following figure.

Figure 8 :



There were fewer altitude changes per aircraft in the low altitude sectors and in one of the high altitude sectors with ODID.

This reduction in altitude changes per aircraft with ODID is related to controllers use of SAC, as described in Section 6.

During the ODID added traffic exercises, in the low altitude sectors there was no apparent increase in use of interim flight levels for transitioning aircraft, whereas in the high altitude sectors there was an increase in flight level modifications to maintain separation.

5.2 SAFETY

The Safety operational construct was defined in Reference 3 as representing the extent to which system variables maintained, enhanced, or degraded relative safety (e.g., the number of system errors, conflict alerts).

This study used four measures to provide information about Safety: Separation Losses, Use of J-Ring, Data Block Offset, and “Other Safety-Critical Issues.”

5.2.1 SEPARATION LOSSES

The separation minima as prescribed in FAA Order 7110.65 is comprised of 5 nautical miles and 2000 feet above FL290, and 5 nautical miles and 1000 feet at or below FL290. A loss of separation, when determined to be the responsibility of ATC, is categorised as an operational error.

There were no operational errors reported in the PVD baseline. No data were provided on losses of separation in Reference 3. There were three losses of separation identified during those ODID exercises that used the baseline traffic samples. Information from ODID recordings along with audio playback of videos taken during the baseline exercises was used to categorise whether or not these losses of separation were operational errors.

Callsigns : CAA111 & DAL897 897
Actual Minimum Separation: 1700’ vertical, 2.11nm lateral
Required Separation Minima: 2000’ vertical, 5nm lateral

The Data Controller determined that DAL897, a B727 overtaking two other aircraft at FL310, required an altitude change and used the conflict detection tools to evaluate options. The VAW indicated that FL350 was not available due to traffic (CAA111) in the opposite direction at FL330. The Data Controller concluded that FL280 was the best alternative and advised the Radar Controller to descend DAL897 to FL280.

The Radar Controller, without using the ODID conflict detection tools, issued a climb clearance to FL350 to DAL897.

A loss of separation occurred between DAL897 climbing through FL347 and CAA111 level at FL330.

Lack of airspace knowledge did not appear to be a contributing factor. The Data Controller was correctly using the ODID tools and realised the possible problem with climbing DAL897 to FL 350, yet the Radar Controller issued a clearance to FL350.

This operational error should be viewed as an endorsement of the ODID conflict detection tools as used by the Data Controller. This situation also calls attention to the potential training and human factors issues involved when the Data Controller is provided with future decision support tools.

Callsigns: AAL529 & LOBO31
Actual Minimum Separation: 600’ vertical, 3.6nm lateral
Required Separation Minima: 1000’ vertical, 5nm lateral

AAL529 and LOBO31 were on frequency and under control of the Sector 26 controller for approximately 5 minutes when LOBO31 was changed to the next sector’s frequency. The radar label for LOBO31 had incorrectly changed to a grey (unconcerned) colour before leaving sector 26 airspace. AAL529 had originally been cleared to FL200 on initial contact. Two minutes after LOBO31 was issued a frequency change, while the Data Controller was co-ordinating via land line with Sector 38, the Radar Controller cleared AAL529 direct to Florence and to climb and maintain FL220.

After disconnecting from the land line, the Data Controller asked why AAL529 had climbed to FL220 underneath LOBO31. The Radar Controller commented that LOBO31 had turned grey and that he had not seen it.

The radar label of LOBO31 had incorrectly changed to a grey colour state prior to crossing the Sector 26 airspace boundary. This was an artefact of the simulation, and would not occur in an operationally deployed system. The cause is that within this ODID simulation, aircraft labels changed to the grey (unconcerned) state upon projected, not actual, sector exit of the aircraft. If for any reason (e.g., vectors or speed control) the aircraft exit from the sector was delayed, the label assumed the grey state prior to actual sector exit. Since the controllers had been trained to view grey radar labels as aircraft of no concern (those outside their sector) the Sector 26 Radar Controller did not “see” LOBO31 during his traffic scan that preceded the climb clearance to AAL529. Had the LOBO31 radar label been the appropriate colour, the controller would probably have seen the traffic, as he had initially, and not issued the climb clearance to AAL529. This loss of separation was viewed by operational experts as a simulation induced incident rather than an operational error.

Callsigns : N863AB & TWA577
Actual Minimum Separation: 300’ vertical, 1.79nm lateral
Required Separation Minima: 1000’ vertical, 5nm lateral

N863AB was northbound crossing the standard instrument departure (SID) route westbound off Raleigh. TWA577 was a Raleigh departure established westbound on the SID. The departure procedure required pilots to climb to and maintain 10000' until cleared by the en route controller to continue the climb.

The Data Controller noticed TWA577 climbing through 11000’ with 10000’ still assigned in the radar label. The Data Controller asked the Radar Controller if he had cleared TWA577 above 10000’ which he had not done. The Radar Controller instructed TWA577 to maintain 12000’ although the aircraft was already through 12000’ in the climb. The highest altitude reached was 12700’.

A loss of separation occurred between TWA577 and N863AB which was level at 13000’.

Neither controller had issued a clearance above 10000’ to TWA577. The aircraft should not have climbed above 10000’ without first establishing communications with the en route controller and then receiving a climb clearance.

This loss of separation was operationally viewed as a simulation induced pilot deviation rather than an operational error.

5.2.2 USE OF J-RING

The PVD J-ring provides a visual range display to indicate a distance of at least five nautical miles from the target to which it is attached. Controllers primarily use the J-ring to monitor separation such as for one aircraft traversing across traffic flows or for a pair of converging or in-trail aircraft.

The focus of the baseline comparison is between the PVD and ODID Radar Controllers since in the PVD environment the Data Controller does not have a dedicated radar display. Comparison of the per aircraft ratio with which the J-ring was displayed by the Radar Controller is shown in the following table.

Table 5 :

	Sector 26	Sector 27	Sector 35	Sector 38
PVD	0.1	0.1	0.02	0.1
ODID	0.2	0.2	0.1	0.1

ODID requires a single mouse click to display or remove a J-ring, whereas the PVD system requires use of a quick action function key followed by multiple keyboard keystrokes or trackball entry. The dialogue method for J-ring display in ODID which requires fewer input actions was considered to have contributed to its increased use by the ODID controllers. The ODID controllers may have made increased use of the J-ring in relation to having less experience with the airspace.

5.2.3 DATA BLOCK OFFSET

As described in Reference 3, the PVD Data Block Offset function is a controller action that orients the data block by altering leader line length and/or direction of offset. Offset is used to maintain unimpeded readability of critical data. Offset is an important component of controller workload, and its frequency of use increases as traffic volume and flow complexity increases.

A secondary use of offset in the PVD environment is as a memory aid where a zero leader length indicates that flight communication has been transferred to the next sector. The PVD baseline data excluded offset message inputs of “slant zero” that were typically not associated with readability of PVD data.

In the PVD single screen system both the Radar and Data Controllers can enter a data block offset message although such inputs are always performed in support of the Radar Controller. For this reason only offset data for the ODID Radar Controller was used for the baseline comparison. Examination of PVD data for message inputs suggested that at least many offset inputs were entered by the Radar Controller.

For purposes of this study, this measure was based on PVD time interval data (Reference 3) that were recalibrated to have 50 and 80 minute measurement intervals similar to ODID. These PVD time interval data combined Radar and Data Controller data block offset inputs.

In ODID the Radar and Data Controllers were able to independently offset data blocks on their respective radar displays with no effect on the display of data blocks on the other CWP. ODID data block offset and movement by both the Radar and Data controller was modified by several system attributes. The primary areas of concern for the controllers arose from the relatively immature state of the ODID automatic anti-label overlap mechanism and also a number of display anomalies which could cause labels to behave unpredictably, particularly in the cases of aircraft turning or at the initial display of an aircraft.

The unimpeded access to radar labels in ODID is important due to the requirement to dialogue with the system via the radar label. The ODID-PVD baseline comparison consists of the following results:

- PVD - total across averages for the 4 sectors of 189.1.
- ODID - total across averages for the 4 sectors of 438.6 for the Radar Controller.

ODID data for frequency of data block offset inputs by the Radar and Data Controllers is shown in the following table.

Table 6 :

	Sector 26	Sector 27	Sector 35	Sector 38
Radar	76.2	99.5	159.4	103.5
Data	108.7	106.6	175.1	117.2

The ODID Data Controller performed more data block offset actions than the ODID Radar Controller across the four sectors. The Data Controller typically employed a smaller radar window in order to accommodate the MTCA tools and also the radar window was set to a reduced zoom so as to show inbound aircraft further from the sector boundary, thereby packing radar labels closer together.

There were several factors contributing to more offset actions with ODID. The ODID Radar Label was larger than the PVD Full Data Block (FDB). The PVD FDB when overlapping another FDB was deemed easier to read than with ODID, due at least in part to font type and character size. With ODID the controllers were more dependent on the Radar Label to access flight information that would otherwise be available on the PVD system paper flight progress strip.

There was also an element of control technique associated with data block offset. Some controllers position data blocks relative to traffic flows to facilitate keeping data blocks apart, for example, in Sector 35 the controller sometimes positioned Radar Labels in different directions for north and south traffic flows.

The table below shows the average percent of time spent per sector for ODID controllers in manipulating Radar Labels across the 50 and 80 minute exercise measurement time periods for sectors 26/38 and 27/35, respectively.

Table 7 :

ODID	Sector 26	Sector 27	Sector 35	Sector 38
Radar	2.0%	2.4%	3.5%	2.6%
Data	2.7%	2.9%	4.1%	3.3%

The ODID Data Controller consistently spent more cumulative time offsetting Radar Labels compared to the Radar Controller. Examination of the number of offset inputs and cumulative time spent moving data blocks showed a high level of variation between individual controllers.

5.2.4 OTHER SAFETY CRITICAL ISSUES

An additional measure associated with the PVD baseline data is “Other Safety Critical Issues.” This measure was based on observation of ATC operations and use of the PVD system during the simulation exercises by an operations expert. No safety issues were reported in the PVD baseline.

In SA5, the multiple measures of ATC operations, the questionnaire techniques, and the controller debriefs and caucus provided sufficient opportunity to identify and collect information about potential controller safety concerns. The controllers did not identify any safety critical issues inherent in the ODID design although some features within the software version used in this simulation were considered unacceptable for operational use.

5.3 PERFORMANCE

As described in Reference 3, the Performance operational construct reflects the controller’s interaction with the system. In the ODID system this interaction is achieved through a complex graphical user interface. PVD measures related to data entry errors for the Radar and Data Controller were based on Host syntactic validity checks, such as inadvertently typing additional digits for an interim altitude assignment. PVD error measures are based on the number of messages returned to the controller for correction. The ODID HMI in many cases does not allow such erroneous inputs.

This study used the following four measures four measures to provide information about Performance as detailed in the following sections :

- Radar and Data Controller data entries
- The number of speed and heading changes
- ATC services
- Task comparisons

5.3.1 RADAR AND DATA CONTROLLER DATA ENTRIES

The PVD measures of Radar and Data Controller Data Entries correspond to the frequency with which different messages were input into the PVD. The ODID-PVD baseline comparison found one message type having some operational equivalency between the two systems. The fundamental differences in dialogue principles and design between these systems limit comparisons using other message types.

The baseline comparison was made for the graphical display of aircraft route on a per aircraft basis. The comparison is only for the Radar Controller in that the PVD Data Controller does not have a radar display on which to display the route. The comparison at the sector level is shown in the following table.

Table 8 :

Radar Controller	Sector 26	Sector 27	Sector 35	Sector 38
PVD Route Display (QU)	0.2	0.1	0.0	0.1
ODID - Baseline Traffic	0.9	1.0	0.6	1.1
ODID - Added Traffic	0.5	0.7	0.3	0.7

As can be seen from this table, ODID Radar Controllers more frequently displayed the flight leg during the baseline traffic compared to the PVD Radar Controller's use of the route display capability. There may have been several reasons for this difference. The ODID flight leg is easier to use because it requires a simple controller input action for display and removal. The PVD route display requires use of a function key followed by some combination of multiple keyboard keystrokes and/or trackball actions. The ODID controller used the flight leg for both route display and conflict detection and analysis information. The PVD controller used the route display for route information only.

The comparison between ODID Radar and Data Controllers on use of the route display on a per aircraft ratio is shown in the following table.

Table 9 :

		Sector 26	Sector 27	Sector 35	Sector 38
Baseline Traffic	Radar	0.9	1.0	0.6	1.1
	Data	0.9	1.0	0.6	0.8
Added Traffic	Radar	0.5	0.7	0.3	0.7
	Data	0.7	0.9	0.6	0.3

The above table shows a comparable level of use of the flight leg capability during the baseline traffic simulation between the ODID Radar and Data Controllers. Examination of individual ODID controller preference on use of the flight leg showed reduced usage for those controllers having operational experience with this airspace.

5.3.2 NUMBER OF SPEED AND HEADING CHANGES

The PVD baseline measure called the Number of Altitude/Speed/Heading Changes was a representation of sector operations relative to the number of changes made by the simulation pilot. This measure was decomposed to its constituent elements for this study due to differences in how altitude changes were measured, as described in Section 5.1.2. Significant variations in simulation pilot speed and heading changes might indicate differences in the way traffic was controlled.

The PVD baseline measure of the Number of Altitude/Speed/Heading Changes was based on the total number of inputs. The ODID-PVD comparisons of speed and heading changes were made using total inputs and a per aircraft ratio. Separate comparisons for speed and heading changes sought to provide sensitivity to system differences relative to control technique.

There is a potential that some PVD pilot data may be skewed high because of duplicate aircraft entries, as was previously described relative to PVD pilot altitude entries in Section 5.1.2 Furthermore, in the low altitude sectors PVD DYSIM pilot speed entries may be high due to adherence, in conduct of the PVD baseline simulation, to a Letter of Agreement between Washington ARTCC and the Raleigh approach control facility regarding departure aircraft not exceeding 250 knots, regardless of reaching 10,000 feet, until the en route controller issues a clearance to resume normal speed. DYSIM automatically accelerates aircraft reaching 10,000 feet through their climb, so one additional DYSIM pilot speed entry would be required to maintain 250 knots. A second DYSIM pilot speed entry would be required when the clearance was issued to resume normal speed. However, examination of PVD data for DYSIM pilot speed inputs showed those counts did not correspond as would be expected with the combined number of departures subject to the Letter of Agreement and arrivals.

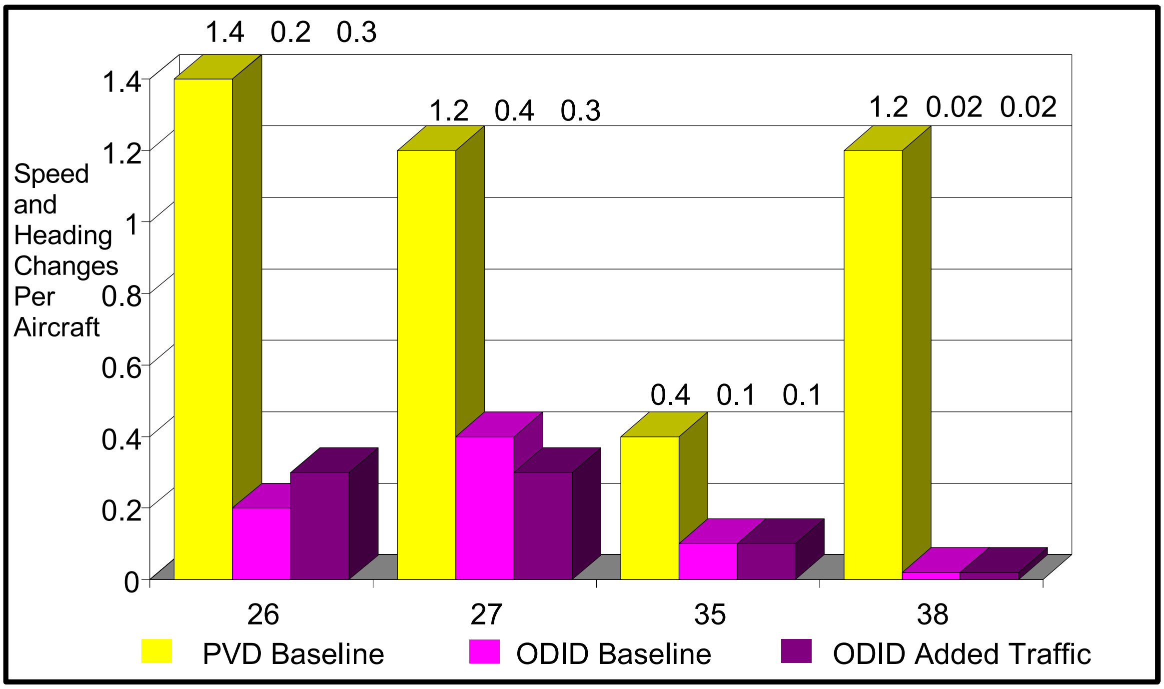
The ODID simulation did not mimic this Letter of Agreement regarding speed control. ODID controller feedback was that ODID pilots had minimal or no influence on simulation exercise results.

The ODID-PVD baseline comparison for the number of speed and heading changes based on all four sectors consists of the following results:

- PVD - average number of speed and heading changes across 4 sectors of 178.6.
- ODID - average number of speed and heading changes across 4 sectors of 27.4.

The baseline comparison for the number of altitude changes per aircraft, as well as the ratio during the ODID added traffic exercises, is shown in the following figure.

Figure 9 :



The comparison in the above figure shows that there was a considerably smaller number of speed and heading changes made by simulation pilots using ODID compared to the PVD.

Comparison of aircraft speed and heading changes at the sector level using the ratio of changes per aircraft is shown in the following table.

Table 10 :

Speed & Heading Changes per Aircraft	Sector 26	Sector 27	Sector 35	Sector 38
PVD	1.4	1.2	0.4	1.2
ODID	0.2	0.4	0.1	0.02

In Sector 26 there were 85% fewer ODID simulation pilot speed and heading changes compared to the PVD simulation pilots. For Sectors 35 and 38 the differences were 75% and 83%, respectively.

This reduction in ODID pilot speed and heading changes is related to controller use of SAC, as described in Section 6. The separate simulation pilot changes for speed and heading changes per aircraft are shown in the following tables.

Table 11 :

Speed Changes per Aircraft	Sector 26	Sector 27	Sector 35	Sector 38
PVD	0.8	0.6	0.2	0.2
ODID	0.01	0.2	0.1	0.01

Table 12 :

Heading Changes per Aircraft	Sector 26	Sector 27	Sector 35	Sector 38
PVD	0.7	0.7	0.2	1.0
ODID	0.2	0.1	0.02	0.01

The above results show that the ODID simulation pilots made fewer speed changes on a per aircraft basis in the adjacent sectors 26 and 38 compared to the PVD controllers. The ODID controllers made fewer heading changes in the high altitude sectors.

For the added traffic exercises the average number of speed and heading changes for the four sectors was 46.3.

5.3.3 ATC SERVICES

The PVD baseline measure of ATC Services provided an indication of the quality of ATC services. The PVD and ODID data were based on controller responses to a questionnaire which was completed following each simulation exercise.

The baseline comparison at the summary level for the Radar and Data Positions consists of results shown in the following table.

Table 13 :

		Radar	Data
1. How good do you think your air traffic control services were from a pilot's point of view? (Rating scale: 1 = not very good, 8 = extremely good)	PVD	6.9	7.1
	ODID	6.7	6.6
2. How well did you control traffic during this problem? (Rating scale: 1 = not very well, 8 = extremely well)	PVD	7.5	6.9
	ODID	6.6	6.9

The PVD Radar Controllers may have rated their ATC services slightly higher than the ODID controllers because of their experience with the airspace and traffic flows, and the number of years using PVD equipment compared to the number of weeks exposure to ODID.

The baseline comparison at the sector level for the Radar and Data Positions is shown in the following table.

Table 14 :

	System	Position	26	27	35	38
1. How good do you think your air traffic control services were from a pilot's point of view? (Rating scale: 1 = not very good, 8 = extremely good)	PVD	Radar	7.0	6.4	7.0	7.3
		Data	6.0	7.6	7.6	7.3
	ODID	Radar	6.2	6.7	6.6	7.1
		Data	6.4	6.5	7.1	6.2
2. How well did you control traffic during this problem? (Rating scale: 1 = not very well, 8 = extremely well)	PVD	Radar	7.3	7.6	7.2	7.7
		Data	6.3	6.8	7.0	7.3
	ODID	Radar	5.9	6.7	7.0	6.6
		Data	6.6	6.5	7.2	7.1

At this sector and position level of analysis, the PVD differences from ODID take on a somewhat different trend. The differences across positions indicate that the PVD controllers had an operational advantage with familiarity with the airspace and confidence from experience in handling traffic flows. This seems to be particularly pronounced for the ODID Sector 26 Radar Position which was deemed to involve a greater challenge for these controllers due to the complexity of the airspace and traffic flow.

5.3.4 TASK COMPARISONS

Another basis for comparing ODID with PVD was the extent to which controllers felt that one system was worse or better than the other. This comparison was made across a derived set of en route controller tasks. The comparisons were augmented with indications of which ODID capabilities helped or hindered the controller.

Controllers completed a task-related questionnaire at the conclusion of the baseline traffic simulation and a second time following the added traffic exercises. The second assessment provided data on how ODID supported controller tasks during higher traffic volumes.

The controllers rated each en route task on a scale that ranged from ‘ODID clearly worse than PVD’ (numeric rating of 1) to ‘ODID clearly better than PVD’ (numeric rating of 5). A numeric rating of three was therefore implied to mean that there was equality between the systems. Average ratings for the controllers are shown in the following table.

Table 15 :

Air Traffic Control Task	Baseline Traffic	Added Traffic
PART I - ATC TASKS		
1. MAINTAIN SITUATION AWARENESS		
1.1 Monitor present air traffic situation (includes checking and evaluating flight data for aircraft separation, sector workload, and traffic flow).	3.2	2.9
1.2 Monitor future air traffic situation (includes checking and evaluating flight data for aircraft separation, sector workload, and traffic flow).	3.1	3.1
2. IDENTIFY AND RESOLVE PROBLEMS		
2.1 Identify impending aircraft-to-aircraft conflict.	3.5	3.1
2.2 Process safety alerts (includes determining clearances, issuing instructions, and ensuring pilot action resolves the situation).	3.4	3.1
2.3 Identify sector workload problem.	2.1	2.4
2.4 Resolve sector workload problems (includes determining its cause, assessing potential resolutions, and co-ordinating a resolution).	3.6	3.0
2.5 Identify deviation from flight plan or clearance.	2.4	2.3
2.6 Resolve deviation (includes determining its cause, assessing potential resolutions, and implementing resolution).	3.1	3.0

3. FLIGHT AND RADAR DATA		
3.1 Support sector team operations (includes co-ordinating display and update of flight data).	3.0	3.0
3.2 Manage information on the radar (situation) display (includes range, map, altitude filters, data block offset, and display lists/windows).	3.4	3.9
3.3 Perform track control functions (includes transfer of control and pointouts).	1.7	1.9
3.4 Request display of flight and track information (includes flight plan readout, J-rings, and vector lines).	3.7	3.5
3.5 Process entry, amendment, and deletion of flight data (includes assigned speed/heading, cleared flight level).	4.0	3.3
4. TRAFFIC MANAGEMENT		
4.1 Integrate departure flows (includes locating departing aircraft, getting aircraft on route and at altitude, providing clearance, maintaining separation, and maintaining traffic flow).	2.6	2.9
4.2 Sequencing arrival flows (includes sequencing aircraft, adjusting aircraft speed/altitude/heading, providing clearance, and maintaining traffic flow).	3.0	3.5
5.0 CLEARANCES AND ADVISORIES		
5.1 Route clearances.	2.7	3.4
5.2 Altitude clearances.	3.5	3.7
5.3 Speed clearances.	3.9	4.0
5.4 Heading clearances.	4.2	4.0
5.5 Traffic advisories.	3.3	2.7
PART 2 - CONTROLLER ACTIONS		
6. HUMAN COMPONENTS OF AIR TRAFFIC CONTROL		
6.1 Support awareness of the ATC situation.	3.7	3.4
6.2 Support your mental understanding of ATC events and other operational factors.	3.3	3.7
6.3 Support applying your knowledge through actions taken.	3.7	3.8

For the baseline traffic, these data indicated that controllers had difficulty with ODID relative to PVD in identifying sector workload problems (Task 2.3) and performing track control functions (Task 3.3). These difficulties were sustained with the added traffic exercises. With the PVD, controllers can readily ascertain current and future workload as a function of how many paper flight progress strips are posted in the strips bays. The PVD system provides workload information with strips printed 30 minutes in advance, whereas ODID was adapted to post flights in the SIL 10 minutes in advance. Control difficulties and procedural ‘workrounds’ with the absence of an ODID handoff capability were previously discussed.

With the baseline traffic controllers indicated that ODID was better than PVD for handling speed (Task 5.3) and heading (Task 5.4) clearances, and this trend continued with the added traffic exercises. With baseline traffic ODID was found better for entering, amending and deleting flight data (Task 3.5) but the extent of this benefit, while still positive, lessened with added traffic. Controller changes to such flight data are more efficiently accomplished through actions in the radar label using pop-up windows.

There were other shifts in controllers' perceptions from the baseline to added traffic exercises which could be due in part to the increased confidence controllers developed in use of ODID. With added traffic controllers showed that ODID was better for managing information on the radar display (Task 3.2), for sequencing arrival flows (Task 4.2), and handling route clearances (Task 5.1). PVD was held to be better with added traffic for handling traffic advisories (Task 5.5), and the two systems ended up with no difference for resolving sector workload problems (Task 2.4).

The task comparisons that controllers assessed included identifying which ODID capabilities helped or hindered the controller. The data was simply a count of how many controllers checked off a capability as being a help or a hindrance on each of the three controller actions identified in the above table. The general results were that SAC was considered as a help by virtually all controllers during the baseline and added traffic exercises. The ODID flight leg capability was also considered to be a help by most controllers. Some controllers indicated that the ERL and CARD were of no help during baseline and added traffic exercises. As previously discussed, the controllers found that the format and data fields comprising the ERL would need modification for use in the United States. From the debriefs it became clear that the CARD had less operational use as a MTCA tool compared to the VAW.

5.4 WORKLOAD

The Workload operational construct represented how hard the controller had to work to perform ATC tasks. In this study workload was assessed using subjective and objective measures. The subjective measures were Average Workload and Post Scenario Workload. The objective measure was Between Sector Co-ordination.

5.4.1 AVERAGE WORKLOAD

Average Workload was derived based on the controllers' subjective workload responses gathered over the course of the exercise. The PVD baseline approach for Average Workload was to prompt controllers to input a workload rating every four minutes. Workload was measured separately for Radar and Data Controllers.

PVD controller workload measurement was based on the Air Traffic Workload Input Technique (ATWIT) that used a seven point rating scale (Reference 11). The ODID Instantaneous Self-workload Assessment (ISA) technique used a 5 point scale. This difference in rating scales precludes a direct comparison between PVD and ODID controller workload ratings and therefore the comparison was limited to examining differences between Radar and Data Controllers in their respective use of the PVD or ODID systems.

The PVD Radar and Data Controller average ATWIT ratings (scale 1 - 7) are shown in the following table.

Table 16 :

PVD	Sector 26	Sector 27	Sector 35	Sector 38
Radar	3.8	3.2	3.1	1.8
Data	2.8	2.4	2.8	2.5

The ODID Radar and Data Controller average ISA ratings (scale 1 - 5) are shown in the following table.

Table 17 :

ODID	Sector 26	Sector 27	Sector 35	Sector 38
Radar	2.3	1.9	2.1	1.8
Data	2.2	1.8	1.9	2.0

The measure of Average Workload provided a perspective on controllers' use of ODID under a higher traffic volume. The ODID Radar and Data Controller average ISA ratings for the Added Traffic exercises are shown in the following table.

Table 18 :

Added Traffic	Sector 26	Sector 27	Sector 35	Sector 38
Radar	2.6	1.4	2.1	2.0
Data	2.2	1.9	2.8	2.3

5.4.2 POST-EXERCISE WORKLOAD

Post-Exercise Workload was measured as part of a questionnaire that both the PVD and ODID controllers completed immediately following each exercise. Post-Exercise Workload was analysed separately for the Radar and Data Controllers.

The baseline comparison for the Post-Exercise Workload measure is shown in the following table. Ratings were on a 8 point scale ranging from 1 (very low workload) to 8 (very high workload).

Table 19 :

	Controller	Sector 26	Sector 27	Sector 35	Sector 38
PVD	Radar	4.0	5.0	5.6	4.0
	Data	3.3	5.2	4.4	3.0
ODID	Radar	5.0	3.2	3.7	3.5
	Data	4.5	3.6	2.9	2.7

There are several trends in the above table. For both high altitude sectors, and for Sector 27, the ODID Radar and Data Controllers reported lower Post-Exercise Workload compared to the PVD controllers.

From an operational perspective, the ODID Radar Controllers may have reported higher workload for Sector 26 due to less familiarity with the airspace and the number of control actions required, e.g., offsetting radar labels for departures from Raleigh airport.

5.4.3 ODID NASA TASK LOAD INDEX RESULTS

A unique component of the SA5 simulation involved obtaining controller subjective workload ratings after each exercise using the NASA Task Load Index (TLX) methodology. These results provide additional perspective on controllers' use of ODID between the baseline and added traffic exercises, as discussed in Section 5.4.1.

Controller workload data were based on a weighted index score ranging from 1 (low) to 20 (high). Results for the baseline and added traffic scenarios are shown in the following table.

Table 20 :

NASA TLX	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline Traffic	7.6	5.1	4.3	5.1	3.9	2.8	3.1	2.0
Added Traffic	10.3	9.2	4.1	6.6	5.9	8.5	5.2	6.3

Some trends found with the Average Workload ISA measure were also shown in the NASA TLX data. For example, comparing the TLX ratings between the baseline and added traffic exercises showed the largest increase for the Sector 35 data position. Also, there was some increase in TLX for the Sector 26 radar position and a decrease for the Sector 27 radar position. However, the TLX ratings for the data position in Sectors 26 and 27 increased from the baseline to added traffic exercises.

5.4.4 BETWEEN SECTOR CO-ORDINATION

Between Sector Co-ordination represents the average communication workload between sectors to accomplish co-ordination. In the ODID simulation environment separate lines were provided to the adjacent sectors and en route and approach control facilities. The ODID controllers were instructed to use land lines rather than face-to-face communication when performing co-ordination.

The ODID-PVD baseline comparison for the total number of calls for the four sectors consists of the following results:

- PVD - average of 39.3 calls.
- ODID - average of 19.4 calls.

From an operational perspective, some percentage of the calls made in ODID may not have been necessary. For example, some calls dealt with aircraft having white radar labels denoting the sector had track control but communication had not yet been transferred to the controller, and calls where SAC had been approved but the aircraft had not yet effected the change.

Operationally, the strategic use of SAC in effecting changes early reduced the number of tactical control interventions.

The baseline comparison at the sector level for counts of between sector calls is shown in the following table (standard deviations provided in parentheses as an indication of the amount of variability relative to average number of calls).

Table 21 :

Co-ordination Calls	Sector 26	Sector 27	Sector 35	Sector 38
PVD	8.3 (7.50)	13.6 (7.20)	7.4 (4.30)	10.0 (4.40)
ODID	5.7 (5.90)	6.2 (3.33)	3.6 (2.07)	3.7 (2.05)

The above table indicates that there was consistently less communication workload for the ODID controllers to co-ordinate changes. In the low altitude sectors there was a reduction in telephone communications by 43%, and in the high altitude sectors by 57%. In addition, the relatively smaller standard deviations associated with ODID suggests more consistency among the controllers in the calls that were made.

The differences in co-ordination calls between the PVD baseline and ODID is due to the ODID controllers' use of SAC, as described in Section 6, and the visibility of ATC constraints in the radar label for aircraft inbound to the sector.

5.5 USABILITY

The Usability operational construct represented the envelope of use of the controller workstation and included the acceptability of controls, displays and other equipment items.

In the baseline comparison the measure was System Usability which was comprised of a series of questionnaire ratings made by controllers on different aspects of the workstation.

Some PVD baseline measures of Usability were not applicable. The measure of Strip Bay Management involves ergonomics associated with use of paper flight progress strips but ODID is a stripless operational environment. The measure of Within Sector Co-ordination involved how PVD and M1 console ergonomics contributed to sector team interactions and these considerations were adapted elsewhere in the comparison methodology.

5.5.1 SYSTEM USABILITY

For this study, the PVD baseline measure of System Usability provided an indication of the practicality of system equipment for use by the controller in providing ATC services. The PVD and ODID data were based on a Final Questionnaire completed after the baseline exercises and after the added traffic exercises.

The PVD baseline comparison with ODID baseline and added traffic is shown in the following table. The rating scale ranged from “strongly disagree” (1) to “strongly agree” (8).

Table 22 :

Practicality of System Equipment	PVD	ODID Baseline	ODID Added Traffic
1. The radar and map display are easy to read.	5.5	4.6	4.7
2. The radar and map displays are easy to understand.	5.7	5.9	5.7
3. There is plenty of space to work within the workstation.	6.1	6.0	6.0
4. The equipment, displays, and controls allow me to control traffic in the most efficient way possible.	5.6	4.5	4.0
5. The equipment, displays, and controls allow me to control traffic without any awkward limitations.	5.1	4.25	3.3
6. Overall, the equipment, displays and controls are effective in meeting the needs of controllers.	5.3	4.6	3.9

Results from these questions showed that the PVD radar and map displays were somewhat easier to read but the PVD and ODID displays are similar in ease of understanding.

Results from the PVD and ODID controllers suggest that there is an analogous amount of space within the workstation.

The ODID controllers rated ODID somewhat lower on the equipment, displays and controls allowing them to control traffic efficiently and without awkward limitations. Some of this difference could be attributed to such considerations in the use of ODID as difficulty in offsetting the Radar Label, the absence of a hand-off capability, and the absence of a keyboard in order to enter fixes for reroutes. This difference in ratings is also seen in terms of the overall lower rating given the ODID equipment in meeting the needs of the controllers.

The second comparison between the PVD and ODID systems is shown in the following table which also indicates the rating scale tailored for each question.

Table 23 :

Ease of Use	PVD	ODID Baseline	ODID Added Traffic
1. Extremely limited (1) to not very limited (8)	3.9	4.6	4.7
2. Extremely frustrating (1) to not very frustrating (8)	3.6	4.7	3.6
3. Not very effective (1) to extremely effective (8)	5.0	5.4	5.0
4. Not very efficient (1) to extremely efficient (8)	5.1	5.4	4.9
5. Not very easy to operate (1) to extremely easy to operate (8)	5.4	5.0	4.9
6. Not very easy to understand (1) to extremely easy to understand (8)	5.4	6.0	5.4

PVD and ODID figures suggest that controllers rapidly adapted to the use of ODID.

The PVD controllers were asked the following questions in order to determine their perception of how potential modifications to the PVD may improve their effectiveness. The ODID controllers were asked these questions from the standpoint of how their effectiveness was changed. The aim of this analysis was to determine the extent to which system improvements actually matched the controller perception of the impact of those improvements. The rating scale ranged from “strongly disagree” (numeric rating of 1) to “strongly agree” (number rating of 8).

Table 24 :

	PVD	ODID Baseline	ODID Added Traffic
1. To what extent do you think a “windows” interface similar to that of personal computers: a. PVD - would improve you effectiveness with the PVD console? b. ODID - improved your effectiveness?	4.8	6.0	5.7
2. To what extent do you think a mouse input device (instead of a trackball): a. PVD - would improve your effectiveness with the PVD console? b. ODID - improved your effectiveness?	1.7	5.0	5.0
3. To what extent do you think colour displays: a. PVD - would improve your effectiveness with the PVD console? b. ODID - improved your effectiveness?	5.2	5.9	6.0
4. To what extent do you think a brighter lighting level: a. PVD - would improve your effectiveness with the PVD console? b. ODID - improved your effectiveness?	2.3	2.6	2.6

The ODID controllers found using a windows interface and a mouse input device to have actually improved their effectiveness compared to the estimation from the PVD controllers. The ODID controllers also reported a slight gain in effectiveness from use of colour displays.

6. SYSTEM ASSISTED CO-ORDINATION AND VERTICAL AID WINDOW

The baseline comparison showed that with ODID there was a reduction in intersector co-ordination calls by approximately 50%. In addition, the comparisons showed the ODID simulation pilots entered fewer altitude changes per aircraft compared to PVD controller altitude message inputs. The ODID simulation pilots also made fewer speed and heading changes per aircraft compared to the PVD DYSIM pilot.

The more streamlined control technique used by the ODID controllers may be due to ODID tools including System Assisted Co-ordination (SAC) and the Vertical Aid Window (VAW) that facilitated identifying trajectories that maintained separation and expedited the flow of traffic.

Some pilot changes were made in the upstream sector because the controller initiated a SAC message effecting sector entry conditions. In addition, the reduced number of pilot inputs in measured sectors with ODID were due to the controller use of SAC with downstream sectors that would allow a flight to continue on its current trajectory.

The frequency of use during the baseline exercises for SAC messages sent by the sector team to the upstream and downstream sectors is shown in the following table.

Table 25 :

	Sector 26	Sector 27	Sector 35	Sector 38
Radar	9.7	8.6	4.1	3.9
Data	4.9	11.2	5.9	3.4
Total	14.6	19.8	10.0	7.3

The ODID Radar and Data Controllers generated an average 51.7 messages for the four sectors to co-ordinate with adjacent sectors. The above data show that for Sector 26 the Radar Controller generated more SAC messages than the Data Controller. The controllers in the other three sectors showed more similarity in their use of SAC.

The above data show that SAC was used by the sector team somewhat more often in the low altitude sectors.

The per aircraft ratio on the use of SAC during the baseline exercises is shown in the following table.

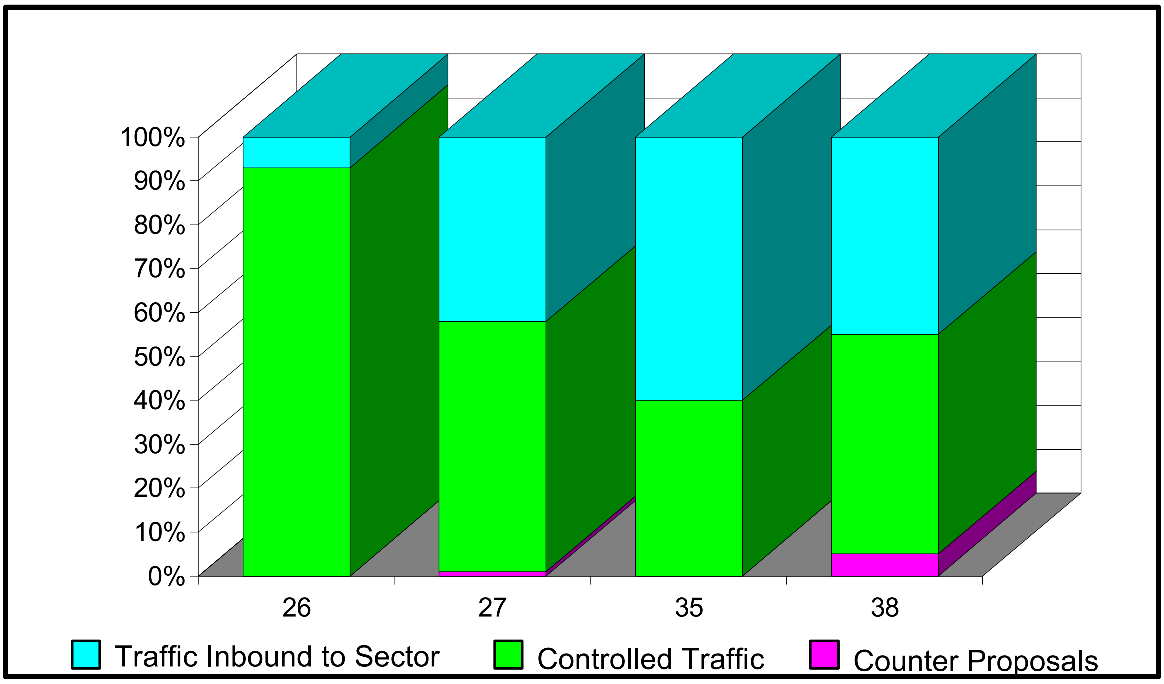
Table 26 :

	Sector 26	Sector 27	Sector 35	Sector 38
SAC per a/c	0.4	0.5	0.2	0.2

A SAC message was generated at a rate in the low altitude sectors of at least 1 in every 2.5 aircraft, and in the high altitude sectors for 1 in 5 aircraft.

The breakdown of SAC messages during the baseline exercises is shown in the following figure for aircraft having pink (traffic inbound to the sector) and white (traffic under sector track control) radar label status as well as for controller counterproposals, as a percentage of the total SAC messages used by the sector team.

Figure 10 :



The statistics for the above figure are shown in the following table.

Table 27 :

	Sector 26	Sector 27	Sector 35	Sector 38
Inbounds	7%	42%	60%	45%
Controlled	93%	57%	40%	50%
Counter-proposals	0%	1%	0%	5%

The decomposition of the frequency of use of different SAC messages by the combined ODID Radar and Data Controllers is shown in the following table.

Table 28 :

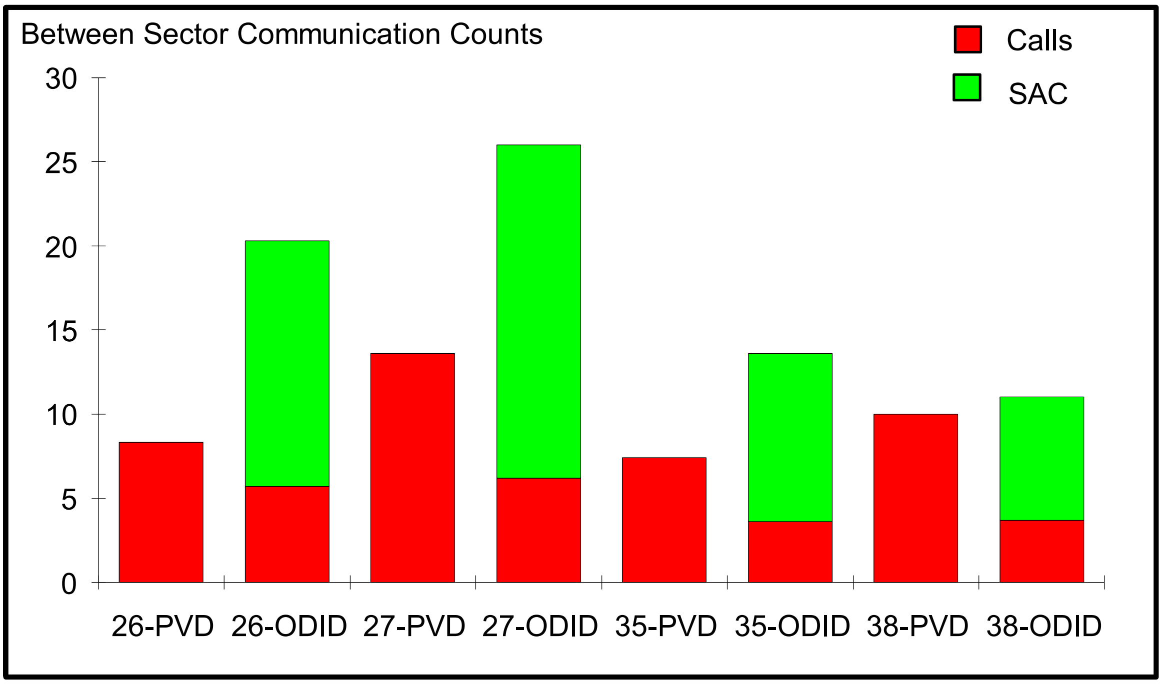
Pink Label	Sector 26	Sector 27	Sector 35	Sector 38
Proposed Entry Level	0.1	0.5	1.1	0.5
Assigned Speed	0	4.5	0.9	0
Exit Flight Level	0	0.1	0	0
Exit Point	0.9	3.2	4.0	2.8
Total	1.0	8.3	6.0	3.3

White Label	Sector 26	Sector 27	Sector 35	Sector 38
Exit Flight Level	5.2	3.3	0.9	0.6
Assigned Speed	0.3	2.3	1.0	0
Heading/ Direct Route	0.1	0.6	0.2	0
Exit Point	8.0	5.2	1.9	3.0
Total	13.6	11.4	4.0	3.6

White Label	Sector 26	Sector 27	Sector 35	Sector 38
PEL Counter Proposal	0	0.1	0	0.4

A comparison between the number of calls comprising the PVD baseline with total ODID co-ordination made through land line calls and all SAC messages is shown in the following figure.

Figure 11 :



The statistics for the above figure are shown in the following table.

Table 29 :

	Sector 26	Sector 27	Sector 35	Sector 38
PVD Calls	8.3	13.6	7.4	10.0
ODID - Total Calls & SAC	20.3	26.0	13.6	11.0
ODID Calls	5.7	6.2	3.6	3.7
ODID SAC	14.6	19.8	10.0	7.3

The figure shows that the ODID controllers effected an increase of some 144% in co-ordination for Sector 26, and over 90% for Sector 27 even though there was a lower traffic count in that sector compared to the PVD traffic count. The ODID controllers effected an increase of over 80% in co-ordination in Sector 35. There are two noteworthy considerations from the discussion of Between Sector Co-ordination in Section 5.4.4. First, there was a drop in the number of land line calls with ODID by 43% to 57% compared to PVD. Second, some calls made with ODID were not operationally necessary but involved simulation conditions. Overall, these differences provide an operational indication of more flexibility with ODID in co-ordinating aircraft changes.

During the added traffic exercises, the frequency of use for SAC messages used by both the Radar and Data Controllers is shown in the following table.

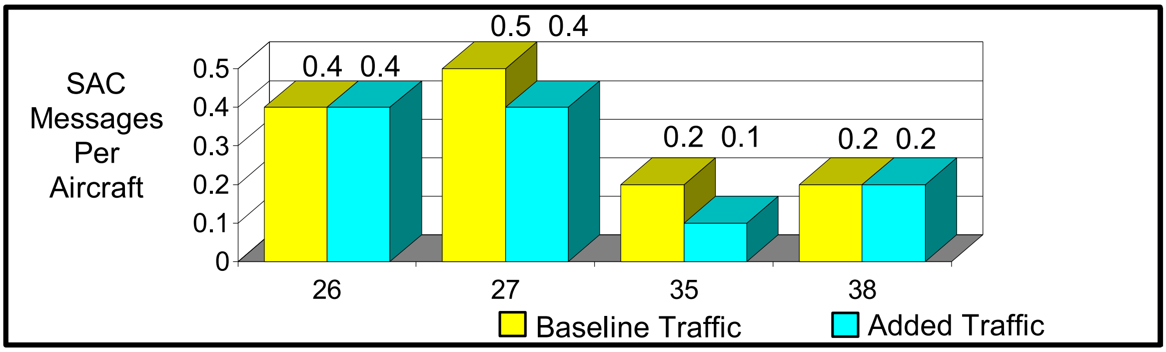
Table 30 :

	Sector 26	Sector 27	Sector 35	Sector 38
SAC Total	20.2	21.5	11.0	9.0

During the added traffic exercises a total of 61.8 messages were generated which is an increase of 20% compared to the baseline traffic exercises.

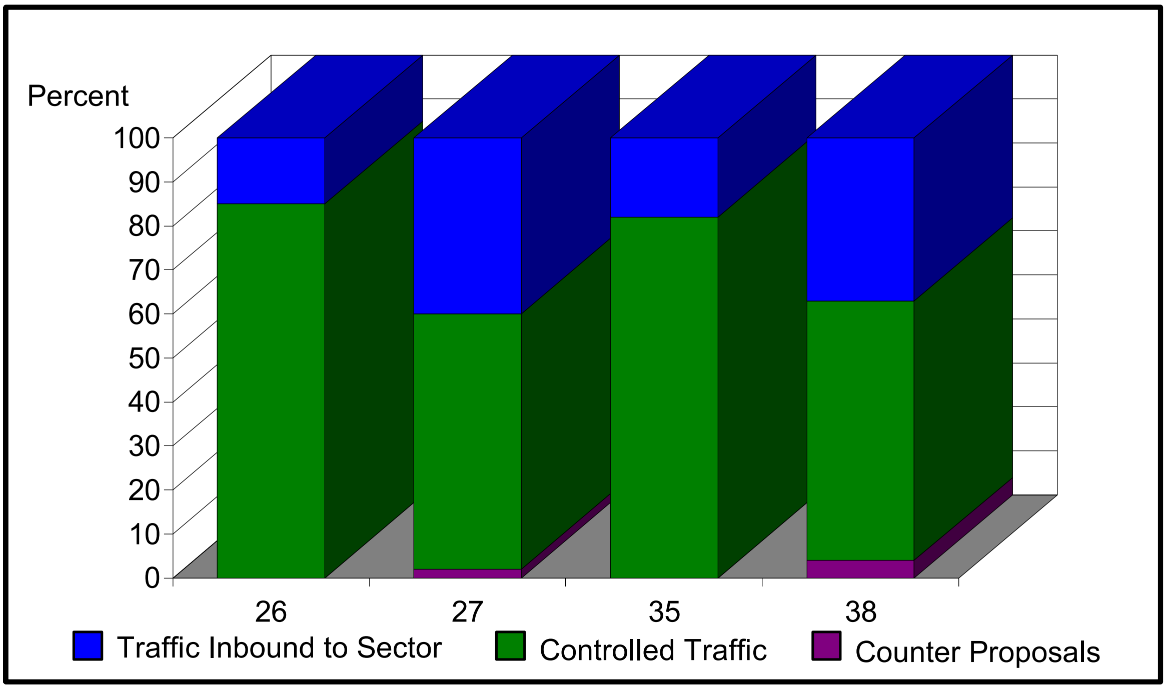
The comparison for the number of SAC messages per aircraft between the ODID baseline and added traffic exercises is shown in the following figure.

Figure 12 :



The decomposition of SAC messages in the added traffic exercises relative to track status as a percentage of the total SAC messages is shown in the following figure.

Figure 13 :



The statistics for the above figure are shown in the following table.

Table 31 :

	Sector 26	Sector 27	Sector 35	Sector 38
Inbounds	15%	40%	18%	37%
Controlled	85%	58%	82%	59%
Counter-proposals	0%	2%	0%	4%

The reduction in ODID co-ordination calls and simulation pilot changes in altitude, speed and heading were also related to controller use of the VAW.

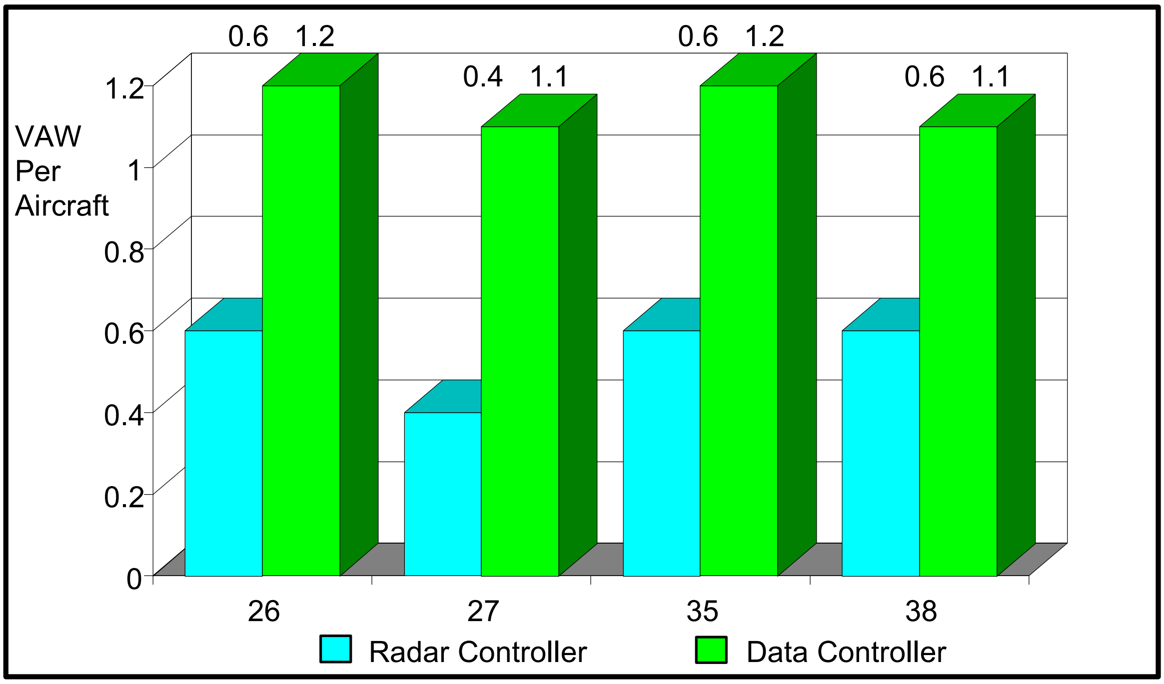
ODID automated recordings were reduced and analysed with regards to controller use of the VAW. The average number of times the VAW was displayed (temporarily and permanently) during the baseline traffic exercises is shown in the following table.

Table 32 :

ODID Baseline	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
VAW Display	18.9	41.0	16.1	43.9	36.0	69.0	18.4	34.7

The per aircraft ratio with which the VAW was displayed during the baseline traffic exercises is shown in the following figure.

Figure 14 :

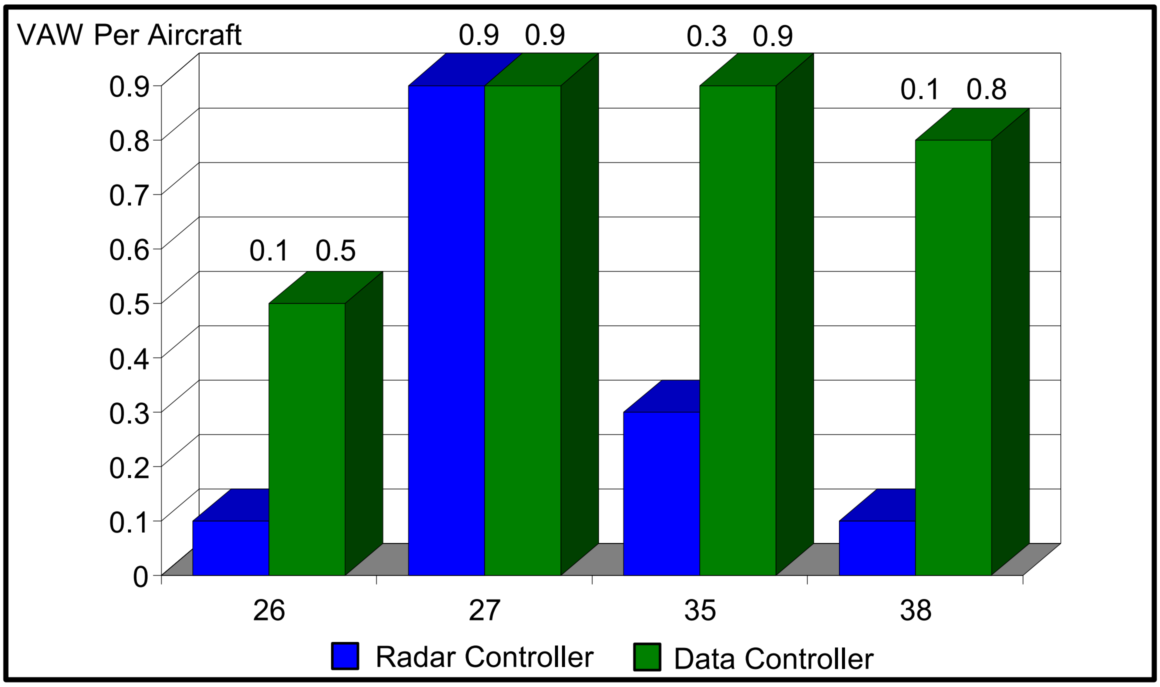


These data suggest some consistent trends in use of the VAW. The Data Controllers reliably used the VAW at a rate of at least once per aircraft, and the Radar Controllers used the VAW at least once for every 2.5 aircraft across low and high altitude sectors. The Data Controllers tended to display the VAW with at least some minor repetition for the same aircraft. There is a possibility that the VAW was not used for some aircraft.

Examination of the data showed a generally consistent trend for both Radar and Data Controllers in which at least 90% of the traffic for which the VAW was displayed were aircraft inbound to the sector having pink radar labels. 10% of the use of the VAW was for aircraft under track control.

During the added traffic exercises, the average number of times the VAW was displayed per aircraft by the Radar and Data Controllers is shown in the following figure.

Figure 15 :



These ratios indicate that the Data Controller in the high altitude sectors (35 and 38) tended to sustain a high rate of displaying the VAW. The VAW was most frequently used by those controllers for traffic inbound to the sector having pink labels, from 86% in Sector 38 to 99% in Sector 35. The VAW was displayed by Sector 27 controllers primarily for traffic inbound to the sector (at least 90%), as well as Sector 26 controllers (at least 64%), compared to display of the VAW for aircraft under track control.

Part of the control technique presented to controllers during the ODID training was to monitor the SIL and when a new posting appeared to display the VAW for that aircraft to check for potential conflicts. Depending upon the nature of any predicted conflicts the controller could also display the flight leg to gain further understanding, and use SAC with the upstream sector to initiate a change in trajectory. The controller could ensure the VAW had been displayed for an aircraft through the corresponding check mark that appeared in the SIL for that posting.

7. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

The findings of the SA5 simulation and PVD baseline comparison were based on the controller operational review and the subjective and objective measures as described in Sections 4, 5 and, 6. The comparative analysis between ODID and PVD sought to identify user benefits and changes in controller productivity.

- **CAPACITY FINDINGS**

The ODID-PVD baseline comparison showed efficiency changes with ODID in which the average flight time was reduced in the two low altitude sectors and increased in one high altitude sector. With ODID there were fewer altitude changes for three of the four sectors.

With ODID, in the low altitude Sector 26 there was a reduction in average flight time of 1.4 minutes (84 seconds) or 12% (11.1 minutes with PVD, 9.7 minutes with ODID), and the variation in average flight times with ODID was about half of the PVD figure, suggesting more consistency or uniformity. There was also a reduced flight time in the low altitude Sector 27 of 0.4 minutes which was a 4% reduction compared to PVD. In the high altitude sectors flight time with ODID was either equivalent to PVD or higher as ODID controllers kept flights on standard routing due to limitations in airspace adaptation.

With ODID there were between 29% and 35% fewer altitude changes per aircraft in both low altitude sectors during the baseline exercises in comparison with the PVD. In Sector 38, there was a 58% decrease in altitude assignments per aircraft and no change in sector 35. During the added traffic exercises, the ODID controllers maintained their baseline per aircraft ratios of altitude changes in the low altitude sectors. There were slight increases in the per aircraft ratios for the high altitude sectors.

This reduction resulted from controllers strategically planning movement of aircraft going through the sector. That is, controllers were trained that as part of their control technique for aircraft inbound to the sector to display the Vertical Aid Window (VAW) to check for potential confliction and to identify conflict free levels, using System Assisted Co-ordination (SAC) to co-ordinate modifications to sector entry or exit altitudes.

SAC had increased use in the low altitude sectors (one message for every 2.5 aircraft) compared to the high altitude sectors (one message for every 5 aircraft). During the added traffic exercises there was a 20% increase in the number of messages generated by the controllers. The ratios of SAC messages per aircraft were maintained in Sectors 26 and 38, and decreased slightly in the other two sectors.

- **SAFETY FINDINGS**

Considering the differences between the PVD and ODID environments, as well as differences in knowledge of the airspace between PVD and ODID controllers, it is difficult to derive specific findings regarding safety. However, several observations can be made regarding the VAW and other ODID MTCA tools.

There were three losses of separation with ODID, one of which was clearly predicted in the VAW and discussed by the corresponding sector controllers. This was interpreted during the operational review to be a positive endorsement of the Decision Support technology. Another loss involved climbing an aircraft but not being aware of a track displayed as a grey label, although subsequent analysis showed that the grey label had incorrectly taken on a non-concerned status as a result of a simulation artefact. A third loss involved a simulation induced pilot deviation. None of these losses were operationally viewed to mean that ODID was an unsafe system.

Controllers indicated that the implementation of trajectory recalculation in this version of ODID software limited the use of the MTCA tools for strategic deconfliction. The VAW was found useful as a planning tool especially for traffic inbound to the sector and particularly for overflights. The Data Controllers displayed the VAW at a rate slightly exceeding once per aircraft.

Information in the CARD was not intuitive and it was frequently overloaded with information. Since the CZW was not updated dynamically, it had limited usefulness.

An additional safety feature identified with ODID is that SAC communications mitigate the potential for errors in communication between controllers. SAC communications are inherently faster than voice communications since identification is implicit in the communication format, and Radar and Data controller verbal communications are reduced.

- **PERFORMANCE FINDINGS**

The comparisons showed several changes in controller productivity. With ODID there were from 66% to 85% fewer simulation pilot speed and heading clearances issued to aircraft. During the added traffic exercises the per aircraft ratios for speed and heading changes were generally maintained at the same low levels across all four sectors. This was attributed to the strategic use of the VAW and SAC.

When considering the relevant merits of the ODID and PVD systems in the execution of their control duties, Controllers reported that ODID was better than the PVD for entering, amending and deleting flight data, managing information on the radar display, sequencing arrival flows and handling route clearances. The PVD was found better for handling traffic advisories and performing track control functions. This is primarily due to the absence of an ODID handoff facility accommodating US ATC operational procedures.

The ODID principle of displaying minimum information and accessing supplementary information on request co-located on the radar display, demonstrated an efficient approach that could eventually replace paper strips. The ODID principles, especially SAC, show highest near term potential for benefits in high altitude sectors and airspace that overlies automated approach control facilities.

The ODID controllers considered the Flight Leg to be a useful feature as it provided a simultaneous indication of aircraft routing and conflict information. The Flight Leg required fewer controller actions to display and remove when compared to the PVD Route Display.

The controllers found several operational advantages with the ODID dialogue design, e.g., ease of data input and information display. SILs provided useful information for traffic inbound to the sector, although adaptation would be needed to cater for more advanced posting times for the Data Controller.

Controllers supported the use of colour to assist them in understanding the ATC situation. There was, however, considerable discussion about the particular colours used in ODID.

Training would need to address how the Data Controller would be enabled to accomplish advanced planning and co-ordination using the VAW and SAC while maintaining situational awareness to support the Radar Controller. Sector team training would be needed.

- **WORKLOAD FINDINGS**

With ODID, inter-sector and inter-facility telephone communications were reduced by 50%. However, there was up to a 44% increase in total co-ordination using ODID (calls plus SAC messages) compared to the PVD baseline (calls only). SAC allowed for silent co-ordination and counter-proposals of altitude, speed, heading and direct routing.

Subjective workload based on a post-exercise questionnaire was lower with ODID for 3 of the 4 sectors compared to the PVD baseline. One workload factor was the difficulty in using the mouse to offset radar labels due to the particular implementation in the ODID software version.

Even though the PVD ATWIT and ODID ISA workload rating scales were different (seven and five points, respectively), ODID Data Controllers' average workload tended to be just fractionally less than the Radar Controller for both low altitude sectors compared to the PVD Radar and Data Controllers.

During the added traffic exercises the ODID controllers tended to show the same average workload as the baseline exercises for the low altitude sectors. The ODID Data Controllers reported higher average workload than the Radar Controllers in three sectors.

- **USABILITY FINDINGS**

Controllers identified changes to the ODID environment that would be required for NAS operations. These included a keyboard to enter fixes for reroutes as well as a hand-off capability to accommodate NAS procedures.

Using a windows interface and a mouse input device was reported by the ODID controllers to have improved their effectiveness compared to the lower impact estimated by the PVD controllers. The use of ODID colour displays was also deemed to have contributed to improved effectiveness.

Over the course of this study EUROCONTROL and the FAA have established the groundwork for close technical co-ordination. Results from this co-ordination have led to meeting all objectives of this study including the provision of an infrastructure to support future simulations and a baselining framework through which results from other studies can be exchanged. The infrastructure is now in place and consists of the Washington ARTCC sector airspace and baseline traffic scenarios that were adapted into the ODID environment. EUROCONTROL has several new and evolving programs any one of which may at some point in time lend itself to a joint simulation using this infrastructure. Experience from this study shows that the airspace could be further expanded to include some of the airspace adjacent to these sectors if necessary.

This study has provided the FAA with increased understanding and insight into how new ATC technologies might contribute to controller productivity or benefit the user.

The baseline comparisons yielded several trends. For the controller these included :

- Fewer calls yet more co-ordination using SAC
- Fewer control instructions issued to aircraft as a result of strategic planning using the VAW and SAC.
- Access to ATC information without paper strips.
- Simpler inputs with mouse button clicks and pop-up menus.
- More information on the radar display such as the flight leg with associated conflict information.
- The use of colour.
- Data controller more engaged in sector operations.

For the user these trends included reduced average sector flight times and fewer altitude, speed and heading changes per aircraft.

The trends identified in these comparisons highlight the types of changes possible with modern ATC technologies as demonstrated in ODID.

It is recommended that the ODID HMI principles form the basis for a technical specification for development as a product improvement for the Display System Replacement program. Further definition is needed in areas such as the formats and fields comprising the radar label and extended radar label, hand-off capability, use of colour, flight leg capability, radar data symbology, and SIL features and adaptation.

This ODID technology provides a framework within which other operational changes should be investigated within, for example, the domains of procedures and sector team training. Studies could consider the role and interaction between Radar and Data Controllers, and also sector operations using a third controller.

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VERSION FRANÇAISE

1. RESUME

La simulation conjointe FAA/EUROCONTROL concernant le système ODID (« Operational Display and Input Development ») a été conçue pour comparer ODID et le PVD (« Plan View Display »), le système actuellement utilisé en route par la FAA. Les résultats de cette comparaison permettront à la FAA de prendre des décisions stratégiques concernant les investissements en matière d'automatisation du contrôle du trafic aérien (ATC). Le système ODID a fait la démonstration de nouveaux concepts technologiques et d'interface homme-machine.

L'objectif de la simulation ODID était d'obtenir des données comparables aux données de référence du PVD qui avaient déjà été recueillies. Les préparatifs de la simulation ont nécessité l'adaptation de l'espace ARTCC de Washington et la modification des échantillons de trafic. L'échantillon de référence PVD était défini à partir des données du « System Analysis and Recording » et représentait 90% du trafic quotidien pour Septembre 1992. Une augmentation de trafic sur certains exercices a permis d'évaluer ODID pour un trafic supérieur de 144% à l'échantillon de référence. Les techniques de mesure comprenaient: un résumé des enregistrements système d'ODID, des questionnaires, les debriefings après les exercices, des enregistrements vidéo ainsi que les mesures de la charge de travail des contrôleurs par le système ISA (« Instantaneous Self-Assessment »).

ARTCCs et le siège de la FAA ont délégué 8 contrôleurs pour participer à la simulation. Parmi eux, l'un travaille actuellement au centre de contrôle de Washington et un autre était qualifié sur le même espace. Tous les contrôleurs ont reçu une formation sur le système ODID, l'espace concerné par la simulation et les procédures. Les contrôleurs ont approuvé la décision de débuter les exercices mesurés sur la base de l'échantillon de référence. En parallèle des exercices ODID, les contrôleurs ont pu à tour de rôle expérimenter le nouvel outil de résolution de conflits d'Eurocontrol: HIPS (« Highly Interactive Problem Solver »).

2. RESULTATS, CONCLUSIONS ET RECOMMANDATIONS

Les résultats de la comparaison entre la simulation SA5 et le PVD ont été obtenus à partir des indications opérationnelles fournies par les contrôleurs ainsi que les mesures subjectives et objectives décrites aux chapitres 4, 5 et 6. L'analyse comparative de ODID et PVD visait à déterminer les bénéfices pour l'utilisateur et les modifications au niveau de la productivité des contrôleurs.

- **RESULTATS CONCERNANT LA CAPACITE**

La comparaison ODID-PVD a montré une amélioration du niveau de service pour ODID avec lequel le temps de vol moyen était réduit pour les deux secteurs inférieurs et augmenté pour l'un des secteurs supérieurs. Avec ODID, il y a eu moins d'instructions de niveaux pour trois des quatre secteurs.

Avec ODID, pour le secteur inférieur 26 et pendant toute la période mesurée, le temps de vol moyen a été diminué de 1,4 minutes (84 secondes) soit 12% (11,1 minutes avec PVD, 9,7 minutes avec ODID), et l'écart type du temps de vol avec ODID était d'environ la moitié, ce qui suggère plus de cohérence. Le temps de vol moyen a aussi été diminué dans le secteur inférieur 27 de 0,4 minutes ce qui correspondait à une réduction de 4% par rapport à PVD. Dans les secteurs supérieurs, le temps de vol avec ODID était équivalent ou supérieur à celui de PVD étant donné que les contrôleurs ODID laissaient les appareils sur leurs routes standards en raison des limites des secteurs adjacents.

Il y a eu, avec ODID une réduction du nombre des changements de niveau de vol de 29 à 35% pour les deux secteurs inférieurs pendant les exercices de référence. Pour le secteur supérieur 38, cette réduction était de 58%. Pendant les exercices avec augmentation de trafic, les contrôleurs ODID ont conservé le nombre des changements de niveau de vol par appareil pour les secteurs inférieurs. Il y a eu une légère augmentation du nombre par appareil pour les secteurs supérieurs.

Cette réduction était due au fait que les contrôleurs pouvaient planifier de façon stratégique les mouvements des appareils qui traversaient le secteur. C'est-à-dire que les contrôleurs organiques avaient reçu l'instruction pendant leur entraînement d'afficher le VAW pour tous les avions qui rentraient dans leur secteur afin de déterminer les conflits éventuels. Les contrôleurs identifiaient également les niveaux qui ne posaient pas de problème avec le SAC qui leur permettait de coordonner les changements tels que le niveau d'entrée ou de sortie du secteur.

Le SAC était particulièrement utilisé pour les secteurs inférieurs (un message pour 2,5 appareils) comparativement aux secteurs supérieurs (un message pour 5 appareils). Pendant les exercices avec augmentation de trafic, le nombre des messages à l'initiative des contrôleurs a augmenté de 20%. Le nombre de messages SAC par appareil est resté le même pour les secteurs 26 et 38 et était légèrement inférieur pour les deux autres secteurs.

- **RESULTATS CONCERNANT LA SECURITE**

Si l'on prend en compte les différences d'environnement entre PVD et ODID, ainsi que les différents niveaux de familiarisation de l'espace pour les contrôleurs PVD et ODID, il est difficile de tirer des conclusions définitives en matière de sécurité. Néanmoins, certaines observations ont pu être faites concernant le VAW et les autres outils MTCA d'ODID.

Il y a eu trois pertes de séparation avec ODID dont l'une avait été clairement prévue avec le VAW comme cela a été confirmé par les contrôleurs affectés au secteur concerné. Ceci a été interprété par les contrôleurs comme étant une validation de la technologie « Decision Support ». Une autre perte de séparation était liée à la montée d'un appareil sans que le contrôleur ait pris en compte la présence d'une étiquette radar affichée en gris. De plus, l'analyse à posteriori a démontré que c'était à la suite d'une erreur du système que l'étiquette s'était affichée en gris (statut « non concerné »). La troisième perte de séparation a été induite par une déviation de route de la part d'un pilote du simulateur. Malgré tout, aucune de ces déviations n'a pu montrer qu'ODID n'est pas un système qui présente les garanties de sécurité indispensables.

Les contrôleurs ont indiqué que l'activation de la fonction de recalcul de la trajectoire dans cette version du logiciel ODID limitait les possibilités d'utilisation des outils MTCA pour une résolution de conflits stratégique. Le VAW s'est avéré utile en tant qu'outil de prévision, tout spécialement en ce qui concerne le trafic qui rentre dans le secteur et particulièrement le trafic de survol. Les contrôleurs organiques affichaient le VAW un peu plus d'une fois par appareil.

L'information contenue dans le CARD n'était pas immédiatement assimilable et le CARD était souvent surchargé d'informations. Le CZW n'étant pas mis à jour suite à l'affichafe initiale, son utilité était restreinte.

Une autre caractéristique du point de vue de la sécurité révélée par ODID est le fait que les communications SAC permettent de réduire le risque d'erreurs liées aux communications entre contrôleurs. Les communications SAC sont par essence plus rapide que celles par téléphone étant donné que l'identification se fait automatiquement, et que les communications sont réduites.

- **RESULTATS CONCERNANT LA PERFORMANCE**

Les comparaisons ont montré certaines modifications de la productivité des contrôleurs. Avec ODID, le nombre d'instructions de cap et de vitesse données aux pilotes de simulateur a été réduit de 66 à 85%. Pendant les exercices avec augmentation de trafic, le taux d'instructions de vitesse et de cap est resté relativement faible pour les quatre secteurs grâce à une utilisation stratégique du VAW et de SAC.

En ce qui concerne la comparaison des systèmes PVD et ODID du point de vue de l'exécution de leurs tâches de contrôle, les contrôleurs ont signalé qu'ODID surpassait PVD pour ce qui est de saisir, de modifier et d'annuler les données des vols, pour la gestion des informations sur l'écran radar, pour organiser les flux des arrivées et délivrer les clairances de routes. Le PVD s'est avéré supérieur pour gérer les informations de trafic et pour effectuer les vérifications de routes. Ceci est dû principalement à l'absence dans ODID d'un outil « handoff » destiné à prendre en compte les procédures de contrôle américaines.

Les contrôleurs ODID ont considéré que le principe d'ODID qui consiste à afficher un minimum d'informations et les compléments à la demande sur l'écran radar a démontré son efficacité et qu'il pourrait remplacer, à terme, les strips papier. Les caractéristiques d'ODID, particulièrement le SAC, présentent des possibilités de bénéfice à court terme pour les secteurs supérieurs et l'espace au dessus des TMAs.

Les contrôleurs ODID ont considéré que le « Flight Leg » était très utile étant donné qu'il fournit à la fois une indication sur la route de l'appareil et une information de conflit. Le « Flight Leg » nécessite moins d'actions de la part du contrôleur pour l'afficher et le désactiver que le « PVD Route Display ».

Les contrôleurs ont trouvé plusieurs avantages du point de vue opérationnel en faveur de l'interface homme-machine d'ODID: facilité pour saisir les données et afficher les informations. Les SILs apportaient des informations utiles concernant le trafic en rapprochement bien qu'une modification permettant au contrôleur organique d'avoir ces informations plus tôt soit nécessaire.

Les contrôleurs ont plébiscité l'utilisation de la couleur pour les aider à comprendre la situation ATC. Il y a eu néanmoins de nombreuses discussions relatives au choix des couleurs pour ODID.

La formation devrait déterminer comment le contrôleur organique peut effectuer à l'avance la planification et la coordination grâce aux outils VAW et SAC tout en restant à la fois suffisamment en prise avec la situation actuelle pour assister le contrôleur radar. Il faudrait assurer la formation des équipes par secteur.

- **RESULTATS CONCERNANT LA CHARGE DE TRAVAIL**

Avec ODID, les communications inter-secteur et inter-centre étaient réduites de 50%. Néanmoins, il y a eu une augmentation jusqu'à 44% de l'ensemble des coordinations via ODID (appels téléphoniques plus messages SAC) par rapport aux chiffres de références PVD (appels téléphoniques uniquement). Le SAC permettait une coordination silencieuse et des contre propositions d'altitude, de vitesse, de cap et de route directe.

Selon les questionnaires qui suivaient les exercices, la charge de travail subjective avec ODID était inférieure à celle de PVD pour 3 des 4 secteurs. L'un des facteurs de cette charge de travail était la difficulté à déplacer les étiquettes radar avec la souris en raison de la version particulière du programme ODID utilisé.

Bien que les échelles des taux de charge aient été différentes pour PVD ATWIT et ODID ISA (respectivement, sept et cinq points), la charge moyenne des contrôleurs organiques ODID avait tendance à être très légèrement inférieure à celle des contrôleurs radar pour les deux secteurs inférieurs par rapport à celles de PVD.

Pendant les exercices avec augmentation de trafic, les contrôleurs ODID présentaient globalement la même charge de travail que lors des exercices de référence pour les secteurs inférieurs. Les contrôleurs organiques ODID ont signalé une charge de travail supérieure à celle des contrôleurs radar dans trois des secteurs.

- **RESULTATS CONCERNANT L'EXPLOITATION DU SYSTEME**

Les contrôleurs ont identifié les modifications nécessaires à l'utilisation de NAS. Celles-ci comprennent l'ajout d'un clavier pour entrer les points des nouvelles routes ainsi qu'une fonction « hand-off » pour prendre en compte les procédures NAS.

Les contrôleurs ODID ont rapporté que le fait d'utiliser une interface à fenêtres et une souris pour saisir les données avait amélioré leur rendement par rapport au moindre impact estimé par les contrôleurs PVD. L'utilisation des couleurs ODID a aussi été considérée comme responsable de l'amélioration de leur rendement.

Pendant toute la durée de cette étude, EUROCONTROL et la FAA ont établi les bases d'une coordination technique étroite. Les résultats de cette coordination ont permis d'atteindre tous les objectifs y compris la réalisation d'une infrastructure destinée à assurer le support des futures simulations et la définition du cadre d'échange de leurs résultats. L'infrastructure est maintenant en place et elle est basée sur le secteur du centre Washington ARTCC et les échantillons de trafic de référence qui ont été adaptés pour l'environnement ODID. EUROCONTROL a plusieurs nouveaux programmes en cours de développement dont l'un pourrait à un moment donné se transformer en une simulation conjointe sur la base de cette infrastructure. L'expérience de cette étude démontre que l'espace utilisé pourrait être élargi pour inclure, si nécessaire, une partie de l'espace des secteurs adjacents.

Cette simulation a apporté à la FAA une meilleure compréhension des nouvelles technologies ATC qui peuvent contribuer à accroître la rentabilité des contrôleurs ou bénéficier à l'utilisateur.

Les comparaisons de référence ont permis de dégager certaines tendances. Pour les contrôleurs, cela signifie:

- Moins d'appels téléphoniques et pourtant plus de coordination grâce au SAC
- Moins d'instructions de contrôle données aux appareils en raison de la planification stratégique via le VAW et le SAC.
- L'accès aux informations ATC sans strip papier.
- Des données saisies plus facilement en cliquant la souris et l'affichage de menus déroulants.
- Plus d'informations sur l'écran radar tels que le « flight leg » et les informations de conflit associées à l'appareil.
- L'utilisation de la couleur.
- Le contrôleur organique plus impliqué dans les opérations de secteur.

Pour l'utilisateur, ces tendances comprenaient un temps de vol dans le secteur qui était réduit et moins d'instructions d'altitude, de vitesse et de cap par appareil.

Les tendances dégagées pendant ces comparaisons mettent en évidence les changements possibles grâce aux nouvelles technologies ATC telles qu'elles sont prouvées par ODID.

Il est souhaitable que les principes HMI d'ODID forment la base des spécifications techniques concernant le développement d'un produit selon le « Display System Replacement program ». D'autres définitions seront nécessaire en matière de format et de champs, y compris: l'étiquette radar,la fonction « hand-off », l'utilisation de la couleur, le « flight leg », la symbolique des données radar, les caractéristiques SIL et leur modification éventuelle.

La technologie ODID fournit un cadre à l'intérieur duquel d'autres modifications opérationnelles doivent être envisagées telles que les domaines des procédures et la formation des équipes par secteur. Les études pourraient s'attacher particulièrement au rôle et à l'interaction entre les contrôleurs radars et organiques, et également à la possibilité d'utiliser un troisième contrôleur par secteur.

Appendix 1: NASA TLX SCORES

NASA TLX scores were based on controller ratings on six different workload factors. These factors were mental demand, physical demand, temporal demand, one's own performance, effort, and frustration. The average controller ratings for each factor by sector, position and traffic level is shown in the following tables.

Mental Demand	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline	8.4	4.6	5.2	5.6	4.9	3.6	2.7	2.6
Added	9.3	8.7	4.5	8.5	5.0	13.5	6.3	8.7

Physical Demand	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline	2.7	2.7	1.1	3.0	2.4	1.4	0.9	1.0
Added	4.3	3.3	1.5	3.5	3.5	3.0	1.3	3.3

Temporal Demand	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline	6.5	4.5	4.6	4.6	3.2	2.0	3.0	1.9
Added	10.3	10.3	3.5	8.0	8.5	8.0	6.7	7.7

Own Performance	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline	5.7	2.6	2.5	5.0	1.5	0.6	2.4	1.1
Added	7.0	0.0	0.5	2.0	2.5	6.0	0.0	4.0

Effort	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline	8.1	7.5	6.0	7.0	5.6	4.2	3.5	2.9
Added	11.7	12.3	6.5	10.5	10.0	10.5	6.0	4.3

Frustration	26 - R	26 - D	27 - R	27 - D	35 - R	35 - D	38 - R	38 - D
Baseline	8.0	5.7	3.2	3.7	4.0	2.6	3.4	1.6
Added	11.7	11.0	3.0	2.0	5.0	7.5	4.3	4.7

In general, increases in traffic appear more related to larger changes in time demand and mental demand, and with the least change in physical demand.

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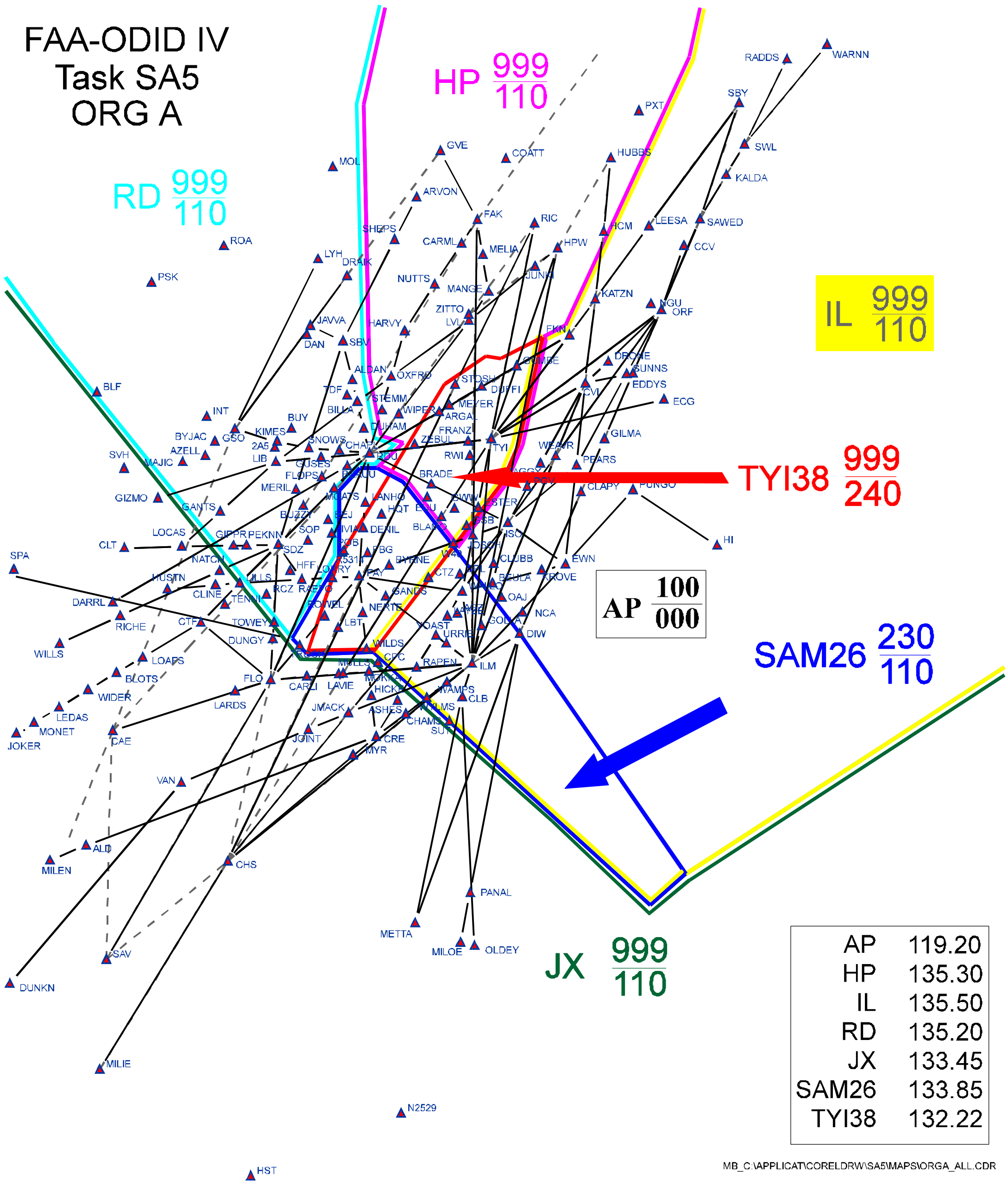
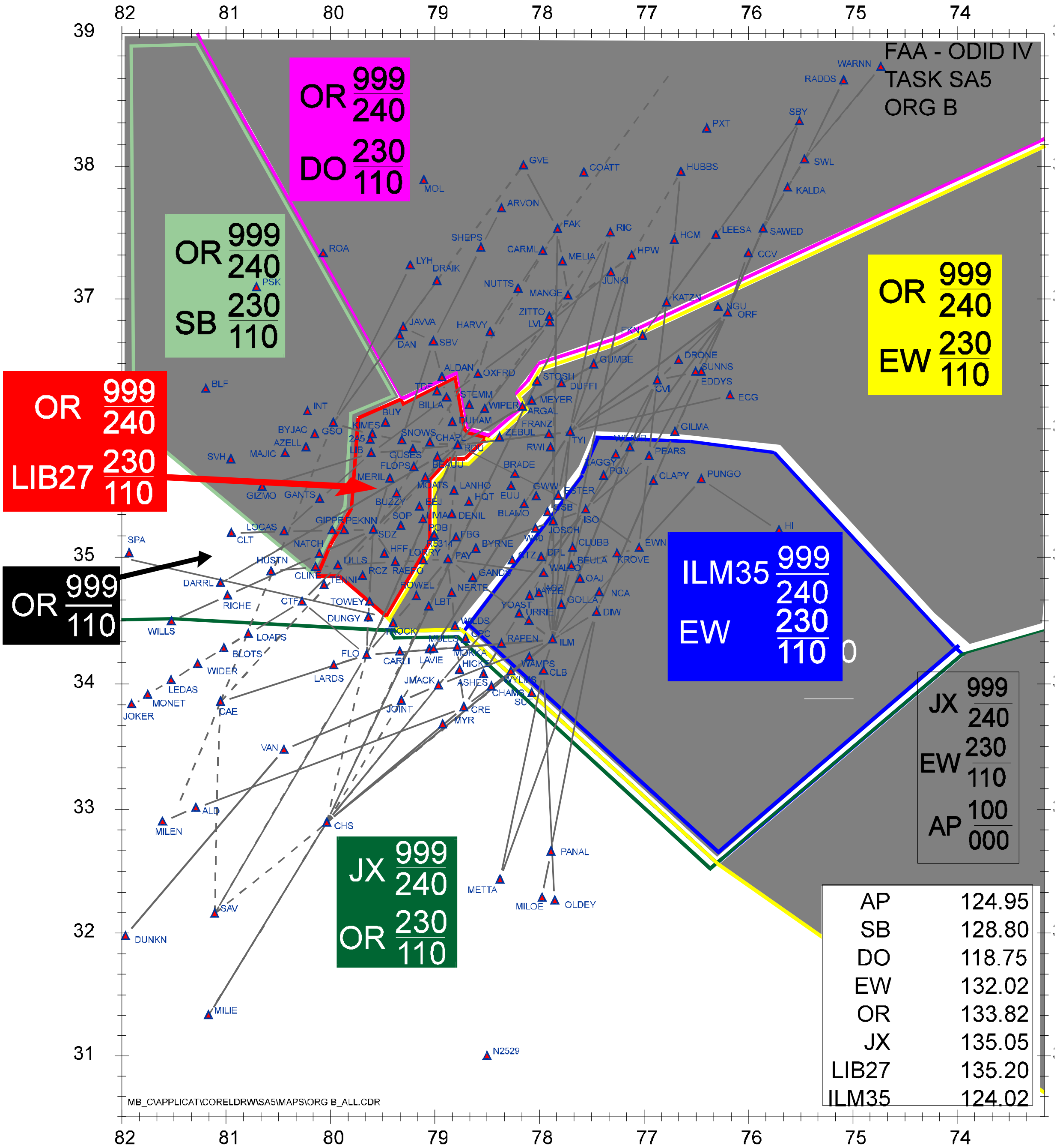
Appendix 1: Simulated Sector Configurations

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EW 230 110
JX 999 240
EW 230 110
AP 100 000
JX 999 240
OR 230 110
AP 124.95
SB 128.80
DO 118.75
EW 132.02
OR 133.82
JX 135.05
LIB27 135.20
ILM35 124.02
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