

En Route ATM Decision Support Tool Computer-Human Interface Requirements Development*

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Abstract

MIT Lincoln Laboratory (MIT/LL) is supporting the FAA-sponsored effort to specify Computer Human Interface (CHI) requirements for the En Route Air Traffic Management Decision Support Tools (ERATMDST) program. The ERATMDST CHI specification is the FAA's vehicle to ensure an operationally suitable user interface is provided for the DSTs (such as conflict probe) to support free flight. The initial draft of the ERATMDST CHI requirements was published in September 1998 and defines an initial CHI which incorporates elements of the NASA CTAS and the MITRE URET prototypes, an Operational Display and Input Development (ODID) display philosophy, and an outline of the end-state CHI. The information will be presented with a consistent, usable look and feel modeled on the advanced human-centered CHI developed by Eurocontrol. This paper describes a CHI Requirements Engineering Model (CREM) and presents preliminary test results of ODID-like display elements in the ERATMDST CHI with controller-in-the-loop simulations presented in terms of workload and response times.

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Introduction

M.I.T. Lincoln Laboratory has built a CHI Requirements Engineering Model (CREM) to support controller-in-the-loop testing of the initial ERATMDST, validate CHI requirements and determine applicable standards for the design of an integrated CHI. The ERATMDST CHI is modeled on Eurocontrol's Operational Display and Input Development (ODID) CHI capabilities and features. The European Air Traffic Control Harmonisation and Implementation Program (EATCHIP) is currently refining ODID with a philosophy and application of design principles that help achieve an operationally suitable user interface.

Our overall project goal is to define the ERATMDST CHI for air traffic controllers, traffic managers and pilots to ensure safe and efficient flight management in both the near to mid-term (circa 2001-5) and the far-term (2008+). For the first time, controllers will have use of automation products that support both scheduling and conflict probe functions. The initial integration of these products and the introduction of an ODID-like CHI to FAA facilities is the focus of our current research. During this timeframe, controller roles will evolve from separate Radar and Data controllers to Air Traffic Service Providers. Similarly, Traffic Management Coordinators will become Traffic Flow Management Service Providers. The research results reported here

describe controller testing of near to mid-term Initial ERATMDST CHI for the Radar position. Figure 1 shows the FAA's Display System Replacement (DSR) console currently being deployed to all en route centers in the United States.

CREM Description

CREM brings to life the EATCHIP philosophy and design principles, where appropriate, in developing an ODID-like CHI for ERATMDST. To achieve an operationally suitable user interface, the ERATMDST CHI will display only minimal information, anchor the cursor position to the most likely selection in a menu of choices, and use color-coded guidance throughout in a consistent manner. The ODID-like EATCHIP interactive CHI, installed by Eurocontrol last year in our ATM laboratory, is currently running on multiple SUN workstations and two Sony 27" diagonal (DSR-type) large screens.

MIT/LL has adapted the EATCHIP demonstration software to FAA sites including Boston and Dallas/Fort Worth. The CREM and pseudo pilot software were also adapted to support controller testing of these sites. Our intent is to produce objective and subjective measurements of controller response times, look and feel preferences, workload and situational awareness of the proposed initial ERATMDST CHI.

CREM uses the Center-TRACON Automation System (CTAS) Traffic Management Advisor (TMA) Plan View Display Graphical User Interface (PGUI) as a baseline situation display for the Radar Position. The situation display has been modified to include certain windows from the User Request Evaluation Tool (URET), such as the Aircraft (A/C) List, and the look and feel of ODID. The URET, PGUI and ODID displays are depicted in Figures 2, 3 and 4, respectively.

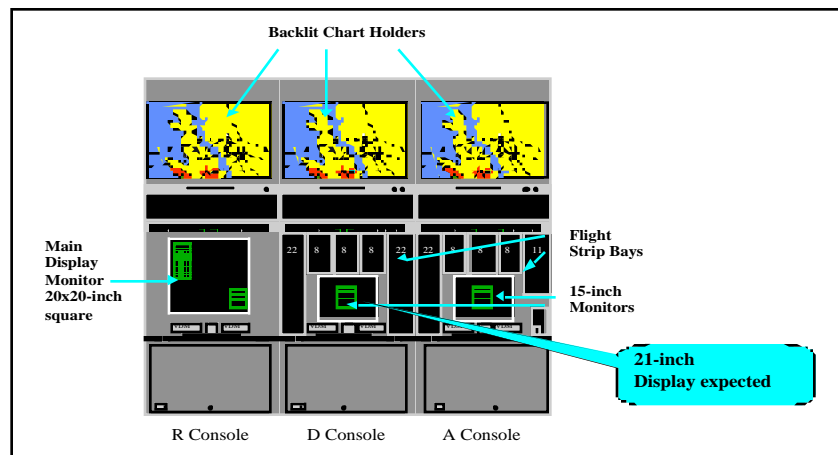


Figure 1. DSR Console.

Aircraft List - Sector 82 - Sorted by: Initial Posting Order						
Delay	CID	Flight ID	Type/Eq	Alt.	BCN	Route
9 Aircraft	0 Proposed Plans	Aircraft ID or CID:		Available centers: None		
1+3	597	UPS2054(unk)	B757/G	370	7321	SDF..IIU.V53.STREP..ROD.J29.JHW./MHT 0000
4+1	777	N788QC(unk)	LR35/R	370	4425	UOX..BWG306029.DAY 0000
2+4	879	NWA99AN(unk)	*DC9/A	330	5132	DTW./MAYZE..ROD.J39.IIU.J89.ATL./MIA 0000
	101	DAL1123	B727/R	330T270	2146	* IND.DAWNN1.BWG./ATL 0000
	596	AAL1636(81)	FK10/G	370	3733	DFW./PXV233019.RID.DAY* 0000
	400	RANDY13(unk)	T38/P	370	6240	CBM./BWG117013.FFO 0000
	567	N953F(83)	C560/R	370	4332	* MCO./DAC0S251032.DQN.MIZAR2.DTW 0000
	396	COM4742(89)	CL65/R	370	5226	MDW./DNY..VHP.FLM..GZG./GSO 0000
	689	NWA435(88)	*DC9/A	370	3535	CVG..CVG.V5.IIU..PXV.J131.LIT./DFW 0000

Figure 2. URET Aircraft List.

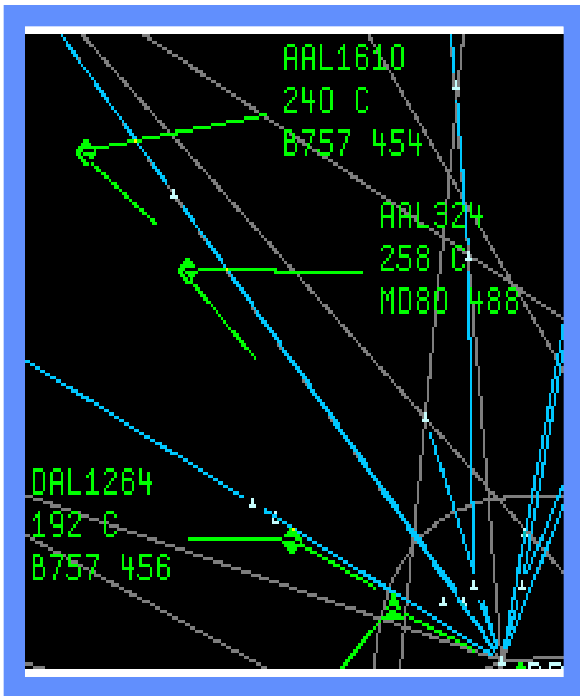


Figure 3. TMA P-GUI.

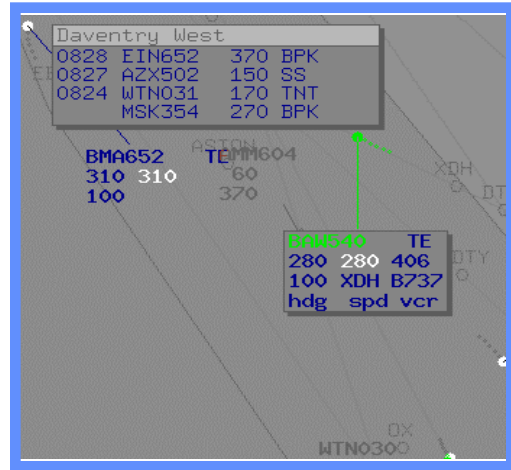


Figure 4. ODID / EATCHIP Display.

The ERATMDST CHI will introduce new display elements, in the form of windows, lists, and fundamentally different interactive data blocks, on both the R and D sides of the DSR console. A general schematic of the R-side is shown in Figure 5, with the existing display elements underlined.

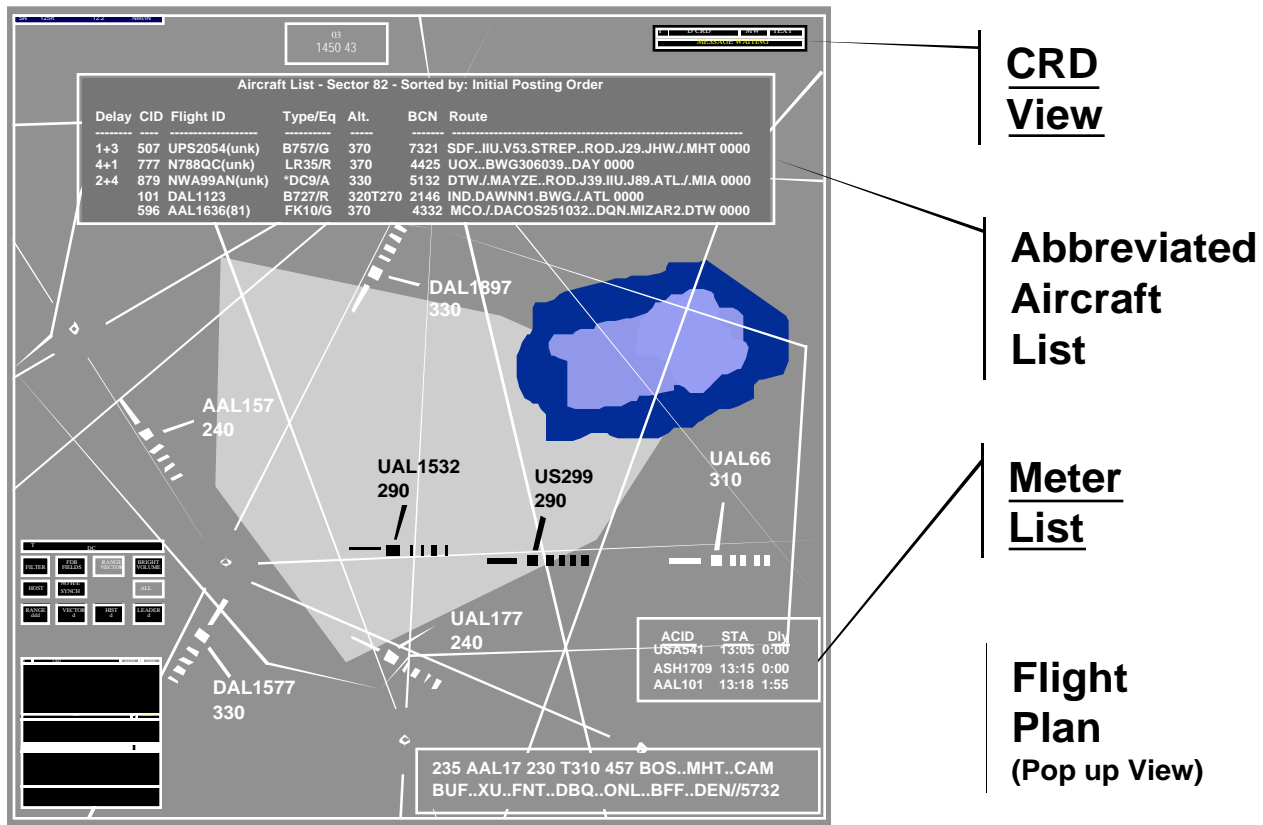


Figure 5. R-side Main Display Monitor (MDM).

CREM test method

A series of CREM tests are ongoing and planned as shown in Table 1. CREM test results will pinpoint

CHI design features and functions found necessary to provide a consistent look and feel across products and platforms.

CREM Tests	S/W Employed	Conditions	Subjects	Test/Spec Dates
Test One	<ul style="list-style-type: none"> • CREM on two SONYs • ODID-like data blocks and lists • Windows • Flight plan pop-up view • A/C and Meter Lists • NASA TLX in EXCEL 	<ul style="list-style-type: none"> • Keyboard Vs. Menu Inputs • Blinking Vs. Color changing Handoffs • System Assisted Coordination 	<ul style="list-style-type: none"> • In-House Controllers • ERATMDST team controllers 	<p>Oct – Nov 1998</p> <p>Initial CHI Internal Draft March 1999</p>
Test Two	<ul style="list-style-type: none"> • Above – plus: • CREM on two D-side 21” monitors • Delay calculation • URET/CTAS conflict detection algorithms 	<ul style="list-style-type: none"> • Above – plus: • Trial Planning • Inter-sector R and D-side teams • Message level integration URET/CTAS 	<ul style="list-style-type: none"> • In-House Controllers • ERATMDST team controllers 	<p>May – June 1998</p> <p>Initial CHI Final Draft September 1999</p>
Test Three	<ul style="list-style-type: none"> • Above – plus: • Multiple SONYs • URET/CTAS conflict resolution algorithms • Elastic vector, other advanced CHI features • DSR-type console for ATSPs • Enhanced End-State ERATMDST algorithms 	<ul style="list-style-type: none"> • Above – plus: • Trial Planning resolutions • Inter-sector ATSP teams • End-state integration URET/CTAS 	<ul style="list-style-type: none"> • Above – plus: • Field Controllers in field 	<p>July – Sept 1999</p> <p>End-State CHI Outline September 1999</p>
Test Four	<ul style="list-style-type: none"> • Enhanced End-State ERATMDST algorithms 	<ul style="list-style-type: none"> • Enhanced CHI functions and features • Final colors • Final look and feel (ODID-like) 	<ul style="list-style-type: none"> • Above – plus: • Field Controllers in field 	<p>Sept – June 2000</p> <p>End-State CHI Initial Draft September 2000</p>

Table 1. CREM Test Schedule.

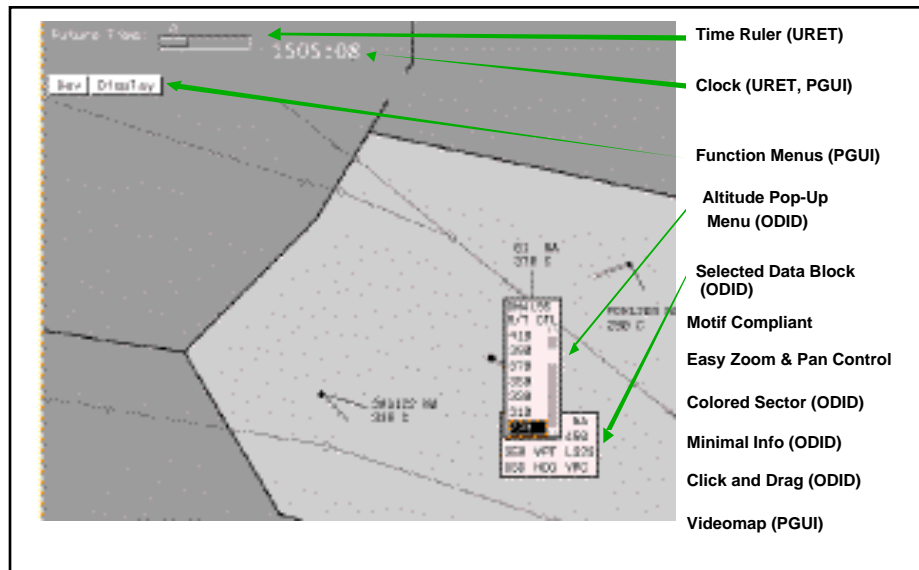


Figure 6. CREM CHI Key Features to Date.

The ERATMDST Graphical User Interface (GUI) will provide such display features as pop-up flight plans, pull-down menus for altitude, speed and heading adjustments, and elastic banding of routes to depict “what if” considerations during trial planning by controllers. The CREM features provided to controllers are highlighted in Figure 6.

Key design decisions yet to be determined include how and where to present these features to the Radar and Data controllers. The CREM provides high fidelity traffic scenarios to address these issues by allowing controllers hands-on experience with various alternatives. Controller coordination levels will be recorded and post-test questionnaires completed by controller subjects to assess workload experienced during the simulations.

CREM Tests

This summer, preliminary part task simulations were conducted with an ODID-like color CHI during approximately 14 hours of shake-down tests using two in-house air traffic control specialists and three pseudo pilots. Tests were conducted using a one hour scenario of realistic ZFW traffic comprised of overflights, departures and arrivals in sectors 47 and 48 with conflicts involving departures climbing through overflights. Data from these tests, along with results from an initial color experiment of various foreground and background combinations, were fed back into the CHI design. Key features and functionality from

both MITRE’s URET and NASA’s CTAS have been integrated into the CREM with an ODID-like look and feel.

This autumn, preliminary test runs were conducted to begin Test One. The subjects were two experienced controllers from the ERATMDST team aided by two other controllers (one from the visiting team and one in-house) serving as pseudopilots. Each subject and pseudopilot was allowed a practice session of about thirty minutes with a playback file. The ZFW heavy traffic scenario was run for approximately one hour during each test session. Subjects were instructed to control the traffic as usual in the field, specifically to feed all the arrivals into a trail exiting to a south or west fix out of sectors 47 and 48, respectively, plus manage the overflights, while accepting all handoffs as soon as the display indication was noticed. The handoffs were indicated by a different color (white versus green for after being accepted) as in ODID. In the first test (Test 1A), the next sector (hand off) field on the incoming traffic datablock was blinking, as it does today in FAA en route centers. In the second test (Test 1B) the field was not blinking, as in ODID. The handoffs were accepted by simply moving the cursor over the target or control position symbol (which is attached to the data block by a leader line) and clicking.

In the first test (Test 1A), subjects changed the altitude of given aircraft within their control

sector by using the new ODID-like menu method. This involved slewing onto the data block, left clicking on the cleared flight level altitude field which automatically caused a menu to appear and then moving the cursor over the desired number in the altitude menu and clicking the left mouse button. An important artefact of the not fully developed CREM software must be noted for this test condition. The cursor would always be resting on the same number as the current flight level when the menu appeared. This number was always the last entry in the visible portion of the menu. This meant the cursor must be moved to select a new altitude. In ODID, the cursor would be resting on the exit altitude, known by the software to be the most likely desired selection. We have yet to program in the exit altitudes based on letters of agreement for procedures used at ZFW. Therefore an extra cursor movement step was needed that will be obviated in future tests.

In the second test (Test 1B), subjects changed the altitude of given aircraft within their control sector by using the existing keyboard method. This involved slewing onto the data block, then typing the letter “a” on the SUN workstation keyboard followed by typing a three digit number and return for the desired altitude. Note that the “a” key was used as a single key stand in for the quick action key available at en route center consoles. A summary of test conditions and features currently available on the CREM for Test One is shown in Table 2.

<p>Automatic data logging of response times</p> <ul style="list-style-type: none"> • Changing altitude via data block menu • Changing altitude via keyboard entry • Indicating handoff via color with blinking • Indicating handoff via color without blinking
<p>ODID-like look and feel</p> <ul style="list-style-type: none"> • Flight plan pop-up by middle click on data block • Multiple menus (scrollable lists) on data block • Drawing entire route of flight
<p>DSR Migration of requirements</p> <ul style="list-style-type: none"> • Font sizes for large screen (SONY 27” diagonal) • Dwell time for cursor (375 milliseconds) • Dwell area for cursor
<p>URET-like aircraft list for R- & D-side</p>

Table 2. CREM Test Features Status.

During the test sessions, all of the handoff acceptance and altitude changes response times were automatically recorded and logged to a file for post-hoc analysis. The start time was at first indication or selection and stop was at completion of action (left-clicking on the target for handoff acceptance or hitting return for altitude change).

CREM test results and analysis

The data reported here are preliminary, and represents only a first look at some key human factors and operational issues identified testable with the CREM to examine the new ODID-like CHI. New tests in the Test One time period (next two months) will produce more valid data to replace the preliminary data reported here, once the CREM software and test techniques have evolved.

Immediately following each test, both subjects completed an assessment of their workload using the NASA Task Load Index (TLX) method. For the parameters of Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Effort (EF), Performance (PF) and Frustration (FR), each subject checked their level on a zero to twenty-point scale. In addition, each subject recorded the importance of each parameter in comparison to each of the other parameters in turn (for a total of fifteen combinations) which resulted in an individually assigned weight (in terms of personal importance). A composite view of controller workload results in terms of weighted ratings is shown in Figures 7 and 8 for each of the parameters plus the overall average weighted workload (WWL) for tests 1A and 1B, respectively.

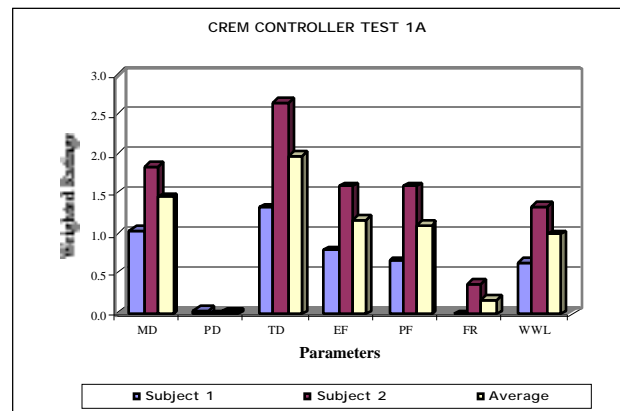


Figure 7. Test 1A Workload Metric (preliminary data).

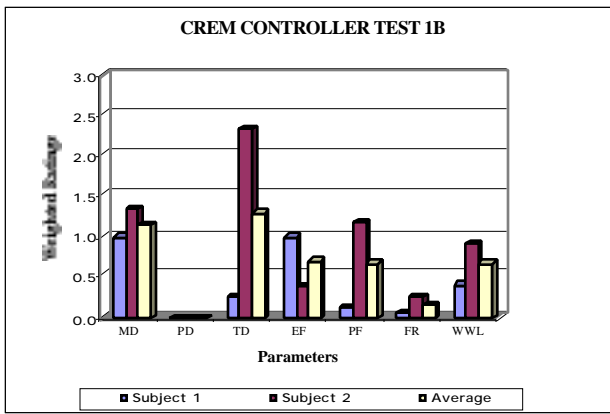


Figure 8. Test 1B Workload Metric (preliminary data).

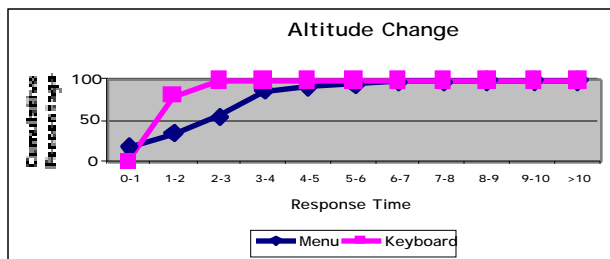


Figure 9. Altitude change response times in seconds (preliminary data).

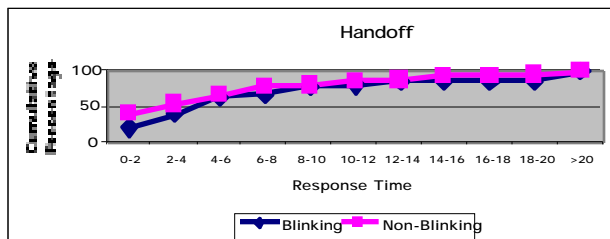


Figure 10. Handoffs response times in seconds (preliminary data).

Controller response times (in seconds) averaged over the two subjects and two test sessions are shown as a cumulative percentage for the two different measures and conditions in Figures 9 and 10 for altitude changes and handoffs, respectively.

CREM test discussion

Controller workload measurements revealed individual differences between the two subjects across the board for all parameters which is not surprising given that subject one has much more recent en route center control experience as compared to subject two who has been retired from terminal control experience for several years.

The only exception of subject two rating performance as less workload than subject one is seen on the effort parameter in the second test undoubtedly because the two subjects switched positions for the test with subject one taking over the much busier sector 48 for test 1B. Note that subject one’s effort climbed slightly for the second test, which is consistent with this finding. The overall weighted workloads decreased in the second test reflecting a decrease across the board in all parameters (except effort for subject one as explained above). This overall decrease is understandable since the controllers were running the same scenario for the second time, albeit at different sectors. More test scenarios and repeated test runs are needed to draw any firm conclusions about controller workload but it is worth noting that none of the workload parameters was given a high rating. Preliminary findings imply that the differences in CHI did not affect controller workload since it was low overall in both test sessions.

Note that, overall, performance in terms of response time was better for the keyboard method of changing altitude in the one to four seconds measurements, with the menu method slightly faster for the below one second measurement, and the two methods converging in performance after about four to five seconds. These data would indicate that the keyboard method is faster, an unexpected result. However, the caveat must be stressed that the menu method was hampered by early software that did not provide the ODID-like feature of a pre-selected cursor position on the altitude menu, which would speed up the entire menu method. The test will be repeated once exit altitudes are determined and the CREM software is upgraded.

The handoff blinking versus non-blinking results in terms of response time revealed only slight differences in overall performance below four seconds which essentially disappeared from four seconds on. Preliminary conclusions from the negligible difference would trend toward a conclusion that the addition of blinking may not cause a faster reaction by a controller accepting a handoff if the data block also changes color, as in ODID. But once again the data are quite early in the test series and only the beginning of Test One where more permutations on the handoff presentation should be considered, such as blinking without color change as is done in en route centers today. Future tests must evaluate reactions of

more experienced center controllers, accustomed to monochrome blinking tags for handoffs, and conversely non-controllers not experienced at responding to blinking or color changing tags. It must be determined the extent to which improved graphics can obviate excessive keyboard entries. It is expected that the use of paper flight strips will be minimized.

Once sufficient CHI maturity is achieved, it will be important to address key functionality issues, such as what is an acceptable level of false alarms and missed detections by the conflict probe software. Demanding traffic loads will be used to challenge the scheduler. Capacity measures will be compared as a measure of usability and acceptability of both the conflict probe and scheduler. Safety, of paramount concern in any new CHI, can be evaluated by assessing operational error rates.

Summary

A preliminary operational concept and initial CHI has been developed by the ERATMDST specification team and reviewed by the FAA operations organization. The initial ERATMDST CHI is based on integration, adaptation, and tailoring of prototypes developed by Eurocontrol, MITRE and NASA. The ODID-like CHI with its minimal information display and color-coded guidance was of particular interest to air traffic, and they suggested simulating the CHI to determine operational suitability.

A CREM has been developed that provides an unprecedented opportunity to allow the controller community early insight and input to the design of the initial ERATMDST CHI and operational concept. CREM simulations have begun and will continue to provide realistic representations of various CHI alternatives and iterate options with controller teams to address user concerns in the ERATMDST CHI design.

This CHI is expected to obviate excessive keyboard entries, minimize use of paper flight strips and provide an intuitively understandable interactive display to increase trial planning capability efficiency and allow a consistent look and feel across products and platforms. Once the initial tests are complete and the methodology refined, more high fidelity advanced tests will be conducted.

The advanced tests to examine end-state ERATMDST CHI will use two DSR-type Sony

20x20 R-Position screens and two 21-inch D-Position screens. Test subjects will include controllers from the ERATMDST specification development team and possibly additional controllers from the URET and/or CTAS field sites. The ERATMDST CHI development process will be completed at the end of this end-state development and test phase.

Acknowledgments

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