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Controller Response to Conflict Resolution Advisory Prototype

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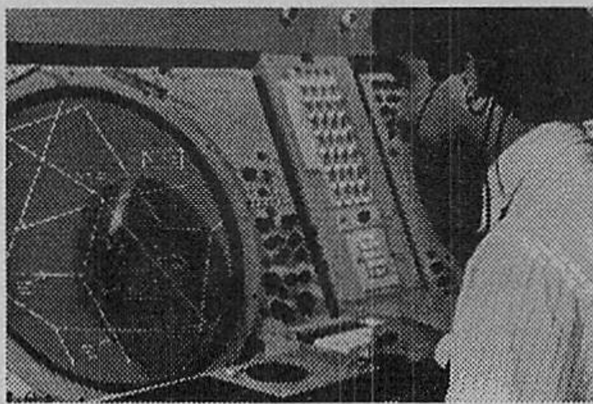

ATC HUMAN FACTORS PROGRAM

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16. Abstract

Conflict Resolution Advisory (CRA) is an automated software aid for air traffic control specialists at air route traffic control centers (ARTCCs). CRA calculates, validates, and displays to the en route controller a single resolution for predicted separation violations detected by the conflict alert (CA) function. This simulation study was conducted to determine controller response time to a CRA message. The response time is the total time required for controllers to notice that the advisory is present, to read and comprehend the text message, and to decide that the resolution is acceptable. Since only the prototype software (CRAU) was available for this test, the only other issue that was formally addressed was controller comments on the CRA message format. The implication of the results of this study for the calculation of the delay that is to be expected between CRA onset and pilot response is also discussed.

17. Key Words

Controller Response Time, Conflict Resolution Advisory

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PREFACE

Conflict Resolution Advisory (CRA) is an automated software aid for air traffic control specialists at air route traffic control centers (ARTCCs). CRA calculates, validates, and displays to the en route controller a single resolution for predicted separation violations detected by the conflict alert (CA) function. This simulation study was conducted to determine controller response time to a CRA message. The response time is the total time required for controllers to notice that the advisory is present, to read and comprehend the text message, and to decide that the resolution is acceptable. This information will be used to modify existing CRA parameters to ensure that the trajectory or path of the maneuvered aircraft is modelled correctly by the CRA algorithm. Since only the prototype software (CRAU) was available for this test, the only other issue that was formally addressed was controller comments on the CRA message format.

This study was sponsored by the Federal Aviation Administration's Automation Engineering Division (ANA-100). We would like to thank all the people who contributed to the development and conduct of this study, including: Larry Reeves of ANA-130 for his technical guidance and for providing the resources necessary to complete the study; John Moore of Martin Marietta for coordinating the efforts of the many key participants; Gary Ellison and Pat Lewis of ACN-110 for their support and the FAA Technical Center and Headquarters personnel who participated as observers.

We are particularly grateful to the many participants from Fort Worth ARTCC. This includes Charles Dukes who led the test effort and provided constant supervision and technical support; the scenario developers Larry Foreman, Michael McCully, Darrell Meachum and Pamela Shedden, who provided expertly choreographed realistic traffic situations; the six test controllers whose talents and patience we taxed; the eight air traffic assistants who acted as DYSIM pilots (including one air traffic assistant each from the Boston and from the Atlanta ARTCCs); and Ron Choate who led and organized the Center's participation and scheduling.

Finally, we would like to thank Alan Yost of ATR-420 and Ron Tornese of Mitre for their tireless and critical technical guidance.

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]\ ^\circ F = y\ ^\circ C$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5)y + 32]\ ^\circ C = x\ ^\circ F$

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 | 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

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EXECUTIVE SUMMARY

Conflict Resolution Advisory (CRA) is an automated software aid for air traffic control specialists at air route traffic control centers (ARTCCs). CRA calculates, validates, and displays to the en route controller a single resolution for predicted separation violations detected by the conflict alert (CA) function. This simulation study was conducted to determine controller response time to a CRA message. The response time is the total time required for controllers to notice that the advisory is present, to read and comprehend the text message, and to decide that the resolution is acceptable.

In Week 1 of the study, three full performance level air traffic controllers were presented with six different two-hour traffic scenarios ranging from moderately high to very high levels of traffic load and complexity. They were instructed to use the CRA message at their discretion. The time between the onset of the CRA message and the beginning of the controller's speech was measured for the conflicts in which the controllers used CRA. This procedure yielded too few data points to adequately assess controller response time.

In Week 2 of the study, three FPL controllers (who did not participate in Week 1) were presented with the same scenarios and told to read and evaluate the CRA messages as they appeared. Response time, defined as the lag between the onset of the CRA message and the beginning of the controller's speech indicating that the resolution was acceptable, was measured. This response time varied from 4 to 30.5 seconds with a mean response time of 12.7 (s = 6.2).

The overall error rate was low. There were only 24 instances (out of 358 occurrences of conflict alert) in which the controller read information into the voice tape that was different from the CRA message that appeared on the Data Analysis and Reduction Tool (DART) printout.

Since only the prototype software (CRAU) was available for this test, the only other issue that was formally addressed was controller comments on the CRA message format. When asked, half of the controllers said that the CRA messages were presented in a format that was easily understood and that the CRA message should be presented on the tabular list.

To calculate the delay that is to be expected between CRA onset and pilot response, the results of this study must be applied to the results of a previous study (DOT/FAA/RD-91/20) that examined the time required for message transmission and pilot response. The analysis of the combined data from these two studies suggests that 40 seconds should be considered as the upper limit on the time expected to elapse between CRA onset and the pilot's initial input into the aircraft's controls.

1. INTRODUCTION

Conflict Resolution Advisory (CRA) is an automated software aid for air traffic control specialists at air route traffic control centers (ARTCCs). CRA calculates, validates, and displays to the en route controller a single resolution for predicted separation violations detected by the conflict alert (CA) function. As with any time-critical warning system, the algorithm must take into account the time required for the operator to use the system. The lag between the time that the CRA message appears on the controller's display and the time that the aircraft begins to maneuver will affect the number and type of potential resolutions.

The purpose of this experiment was to determine controller response time to a CRA message. The response time is the total time required for controllers to notice that the advisory is present, read and comprehend the text message, and to decide that the resolution is acceptable. This decision process is important. Some resolutions that CRA provides are not useful as the system cannot take into account all of the information available to the controller. CRA may, for example, offer a resolution that turns an aircraft into restricted airspace or toward a thunderstorm cell, since the CRA logic contains no information on restricted airspace or weather. This data on controller response time will be used to modify existing CRA parameters to ensure that the trajectory or path of the maneuvered aircraft is modelled correctly by the CRA algorithm.

This test was conducted during the development phase of the enhanced CRA (CRAE) software. Since the prototype version (CRAU) was used for this test, the only issues that were formally addressed were controller response time and controller comments on the CRA message format. Also, response times were only examined for the first resolution offered; updates to the original advisory were not examined, as the display format for updates will be different in CRAE than it was for the prototype.

2. METHOD

This simulation study was conducted over a two week period at the DYSIM laboratory facilities at the FAA Technical Center in Atlantic City, NJ. The procedures for Week 1 were the same as for Week 2, with the exception of a change in the instructions to the test controllers. In the first week, the controllers were instructed to use the CRA display based on the currently anticipated procedure; use of the display was optional and at the discretion of the controller. For Week 2, controllers were instructed to look at the CRA display when it appeared, read the resolution aloud and state whether or not the resolution was acceptable.

CRA Display

The CRA messages appeared in the tabular list. Figure 2-1 shows examples of CRA messages as they appeared to the test controllers. A maximum of one resolution was presented per conflict alert. Resolutions can involve vertical or horizontal maneuvers. A vertical maneuver can consist of a climb, a descent, or a maintain (i.e., a level-off maneuver when the aircraft is already either climbing or descending). The controllers were able to change the location of the tabular list on the screen display.

FIGURE 2-1. EXAMPLES OF CRA MESSAGES

Example 1: Single horizontal maneuver required

```
Conflict Alert
   .AAL210   UAL202    01   04[1]
   R[2] AAL210
   R UAL202[3] R30[4]
```

Example 2: Single vertical maneuver required

```
Conflict Alert
   .AAL210   UAL202    01   04
   R AAL210
   R UAL202        ↑290[5]
```

Example 3: Joint maneuver required

```
Conflict Alert
   .AAL210   UAL202    01   04
   R AAL210  R30
   R UAL202  L30
```

Example 4: Multiple pair conflict, one maneuver required

```
Conflict Alert
   .AAL210   UAL202    04   04
   .UAL202   COA301
   M[6]
   R AAL210
   R UAL202        ↓200
   R COA301
```

---

[1] Conflict Alert tabular list with intersector notation

[2] "R" for single maneuver required (appears in CRAU only) or "J" for Joint (two maneuvers required)

[3] AID for CRA aircraft

[4] Horizontal maneuver - right or left turn in degrees

[5] Vertical maneuver - climb, descend, or maintain

[6] CRA designator for multiple pair conflict

3. WEEK 1

3.1 METHOD

Subjects

Subjects were selected from a list of volunteers from the Ft. Worth ARTCC. They were three full performance level (FPL) controllers who currently work in the sectors that were simulated for this study.

Airspace

The airspace simulated consisted of three contiguous test sectors. Two of these sectors were high altitude sectors (Dallas High and Ardmor High) and the third was a low altitude sector (Frisco Low). These test sectors were supported by a controller on a "ghost" sector. The ghost sector initiated and received aircraft but was not a test sector.

Scenarios

Six different scenarios, each approximately 1 1/2 to 2 hours in duration, were developed based on actual traffic from the sectors chosen for simulation. To insure the occurrence of conflicts, the scenarios were constructed to range from moderately high to very high workload (in terms of number of aircraft and traffic complexity). The scenarios contained emergencies and other unusual conditions (e.g., no radio) and one of the scenarios contained significant weather conditions. Simulated aircraft were operated by experienced DYSIM pilots. The scenario developers worked with the DYSIM pilots and were able to make immediate adjustments to the traffic loads, as necessary.

Procedure

Controllers were instructed to work as they normally would in that sector, following standard operating procedures. Each controller worked alone as there were no D-side (radar associate) controllers. Before the first test session, the controllers were briefed on the functions and limitations of the CRA prototype program and were given a description of the display. The prototype software displayed the resolution on the tabular list from the onset to the offset of the conflict alert. The test controllers' instructions were based on the currently anticipated procedure, that is, that use of the CRA display is to be considered optional and at the discretion of the controller (Floyd Etherton, ATP-130, personal communication).

Two different scenarios were run each day (between 6:00 p.m. and midnight) over three days for a total of six experimental sessions. During each session, observers who sat behind the controllers recorded the call signs of the aircraft involved in the conflict, the content of the CRA message, and the controller comments on the CRA message. The observers also recorded whether the controllers used the CRA display; this was judged to be the case if the controllers looked at the message and issued the same clearance to the aircraft. The communication frequencies were recorded on audiotape so that the time between the onset of the CRA message and the onset of controller speech as they issued the CRA maneuver could be measured. The time of the onset and the content of the CRA message was taken from the Data Analysis and Reduction Tool (DART) printout.

After each test session, controllers completed questionnaires that asked for their opinions on the realism of the scenarios and the perceived workload of the scenarios. After the controllers' participation in the study was completed, they filled out a questionnaire that asked for additional written comments on the CRA message format and the realism of the simulation.

Only the instances in which the controller used the CRA message were used to determine the controller response time to the CRA message. Since the purpose of the study was to determine the component of the delay parameter in the CRA algorithm attributable to controller response time, instances in which the controller would not use CRA were not applicable.

3.2 RESULTS

Questionnaire Analysis

Controllers rated the realism of each scenario on a scale of one to five. A score of one was equivalent to "very unrealistic", three was "moderately realistic" and five was "very realistic". The arithmetic mean (average) of all six scores collapsed across scenarios was 3.4 (standard deviation (s) = 1.4). Subjective workload measures of the scenarios consisted of measures of the amount and complexity of the traffic presented. Controllers rated the traffic load and complexity compared to what they normally see on that sector. Traffic load estimates ranged from 50% to 150% across scenarios with a mean of 99% (s = 24). Measures of traffic complexity ranged from one ("very simple") to five ("very complex") with a mean of 3.9 (s = 1.2).

Voice Tape Analysis

In the 16 hours of testing in Week 1, there were 16 instances in which the controller issued the CRA maneuver after it appeared on the display. For two of these instances, there was a malfunction that caused a delay in the CRA display so that the resolution appeared seconds after the onset of the conflict alert. The remaining 14 instances in which the CRA display worked properly were analyzed for controller response time.

Of the 14 CRA resolutions that the controllers used, seven involved descend maneuvers, six were maintain maneuvers, and one involved a right turn.

The time between the onset of the CRA message and the onset of controller speech varied from 2 to 40 seconds. The mean response time was 18.4 seconds (s = 10.4) and the median (response time at the 50th percentile) was 16.7. The individual differences in response times were notable. One controller used CRA three times during the course of the study and the mean response time for that controller was six seconds. Another controller used CRA seven times with a mean response time of 24 seconds. The third controller used CRA four times with a mean response time of 18 seconds.

Because the voluntary use of CRA during Week 1 of the study resulted in too few data points to adequately determine response time, the procedure was changed for Week 2.

4. WEEK 2

4.1 METHOD

Subjects

Three full performance level controllers were selected for participation in the same manner as described for Week 1. They currently work in the sectors that were simulated for this study and had not participated in Week 1.

Airspace and Scenarios

The airspace simulated, and the scenarios used, were the same as described for Week 1, with one exception. More traffic was added to one of the sectors after the controller from Week 1 and the scenario developers thought that the sector was not as busy as the other two sectors.

Procedure

The procedure for Week 2 was identical to that for Week 1 with one exception. The instructions to the controllers were to look at the CRA display when it appeared, read the resolution into the tape (i.e., after keying the microphone), and state whether or not the resolution was acceptable. The instructions stressed that the controller did not have to use the resolution offered by CRA, even if he/she found the resolution acceptable. A resolution was to be judged acceptable as long as it was perceived to be an effective solution.

4.2 RESULTS

Questionnaire Analysis

Controllers rated the realism of each scenario on a scale of one to five. A score of one was equivalent to "very unrealistic", three was "moderately realistic" and five was "very realistic". The mean score collapsed across each scenario was 3.9 (s = .97). Subjective workload measures of the scenarios consisted of measures of the amount and complexity of the traffic presented. Controllers rated the traffic load and complexity compared to what they normally see on that sector. Traffic load estimates ranged from 60% to 150% across scenarios with a mean of 105% (s = 23). Measures of traffic complexity ranged from one ("very simple") to five ("very complex") with a mean of 3.4 (s = 1.1).

Voice Tape Analysis

There were 358 occurrences of conflict alert encountered by the three controllers during the 12 hours of testing in Week 2. Table 4-1 categorizes the controllers' responses to these alerts. CRA messages generated as a result of a nuisance conflict alert or when all of the conflict aircraft were not in voice communication with the test controller (i.e., under track control only) were ignored by the controllers. An additional 60 CAs/CRAs were not commented on by controllers. In 38 instances of CA, CRA did not offer a resolution. This left 125 instances of CRA where the resolution was evaluated by controllers as either acceptable or not acceptable.

TABLE 4-1. CONTROLLER RESPONSES TO CA/CRA

Controller Response	Frequency
Resolution Acceptable	90
Nuisance Alert	90
No Comment on CA/CRA	60
Aircraft Under Track Control Only	45
No Resolution Available	38
Resolution Unacceptable	35
Total	358

Acceptable Resolutions. In 25% of the total CAs (72% of the 125 CRA messages evaluated by controllers), the resolution was considered acceptable. In 5 of these 90 instances, there was a malfunction that caused a delay in the CRA display so that the resolution appeared seconds after the onset of the conflict alert. The remaining 85 instances in which the CRA display worked properly were analyzed for controller response time. Of the 85 responses analyzed for response time, 34 were attributable to one test controller, 29 to another, and 22 to the third.

The time between the onset of the CRA message and the onset of controller speech indicating an acceptable resolution was measured. For example, if the controller's response was, "CRA wants to turn United 123 right thirty degrees . . . yeah, that will work", the end of the response time was measured as the beginning of the "yeah." This response time varied from 4 to 30.5 seconds (see Table 4-2). The mean response time was 12.7 seconds (s = 6.2). Table 4-3 shows the response times at several percentiles.

TABLE 4-2. CONTROLLER RESPONSE TIME (IN SECONDS)

Minimum	4.00
Maximim	30.50
Mean	12.72
Standard Deviation	6.18

Total Number of Observations = 85

TABLE 4-3. CONTROLLER RESPONSE TIME (PERCENTILES)

5th	6.0
10th	7.0
50th	11.0
90th	22.0
95th	26.0

The variability among controllers in terms of response times was small. The mean response time for one controller was 11 seconds (s = 4.9), for another was 13.2 (s = 6.5), and for the third controller was 14.7 (s = 6.9).

Nuisance Alerts. Twenty-five percent of the CA instances were considered by the controllers to be nuisance alerts. Resolutions to nuisance CAs were not evaluated by the controllers. Independent from the controllers' observations, a CA was classified as a nuisance alert by the controller observers when no action was required by the controller to resolve the potential conflict. There were only a few instances in which the controller classified the CA as a nuisance alert when the observer did not.

No Comment. In 60 (17%) of the 358 instances of conflict alert the controller did not comment on the CA or CRA message. Most (45) of these instances were due to the controller not mentioning that a CA was occurring; many of these instances could be attributable to nuisance alerts (as noted by the observers). Seven instances were due to the controller noting that there was a CRA message but giving no comment. Four instances were due to the CRA message disappearing before the controller could read it and four were due to the tabular list being too cluttered to read effectively.

Advisories for Aircraft Under Track Control Only. Thirteen percent of the CAs involved aircraft that were not in voice communication with the test controller. Resolutions that were presented to the test controller, but were intended for aircraft under track control only (and not in voice communication with the test controller) were not evaluated by the controllers.

No Resolution Available. In ten percent of the 358 instances of conflict alert, CRA did not generate a resolution. In these cases, the spaces that normally contained the resolution were blank.[7]

Unacceptable Resolutions. In ten percent of the total CAs, the resolution was considered unacceptable. This does not include the instances in which the CRA resolution given to the controller involved maneuvers for aircraft not in voice communication with the test controller. The controllers' reasons for judging the resolutions to be unacceptable were not examined in detail, since they will change with the implementation of CRAE.

Controller Response Errors

Occasionally, a controller would read information into the tape that was different from the CRA message that appeared on the DART printout. Since no video of the tabular list was recorded for this test, a discrepancy between what appeared on the scope and what was on the DART printout cannot be ruled out. However, such a discrepancy appears improbable.

Even though the overall error rate was low, the errors were analyzed in detail. This analysis was conducted for the purposes of trying to predict what types of errors controllers could be expected to make with CRA so that the probability of these errors could be minimized in the future.

There were 24 instances (6.7% of the 358 CAs) in which the controller read information that was different than what was recorded on the DART printout as appearing on the tabular list. These misreads and misspeaks (i.e., meaning one thing but saying another) are divided into five categories and tabulated in Table 4-4.

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[7]This is only true for the prototype software. In CRAE, the message "no res", meaning no resolution is available, will appear.

TABLE 4-4. CONTROLLER MISREADS OF CRA MESSAGES

Controller Response	Frequency
Misreading the Maneuver	9
Misreading the Aircraft Call Sign	8
Reporting No Resolution (when one appeared)	4
Assigning the Maneuver to the Wrong Aircraft	2
Miscellaneous	1
Total	24

Misreading the Maneuver. Controllers reported a maneuver that was different from (but, in most cases, very similar to) the CRA message in 37.5% of these misread instances. A maneuver was reported in the same direction, but of different magnitude in four of these cases; for example, "Right 40" was read as "Right 70 degrees." In one instance, the opposite direction was reported ("Right 40" was reported as "Left 30"). In two cases, the controllers thoroughly misread the CRA message; "Maintain 300" was reported as "Right on both aircraft" and "Descend 260" was reported as "Right, but it doesn't say how many degrees." These last two cases, in which the controllers thought the maneuvers involved right turns, are probably attributable to the "R" that indicated that the resolution involved only one maneuver (as opposed to a joint maneuver). This "R" will not appear in the CRAE display.

Misreading the Aircraft Call Sign. Thirty-three percent of the 24 instances involved misreading the aircraft call sign. This includes instances in which the numbers in the call signs are transposed or the airline is misidentified with the correct flight number. In none of these instances did the controller catch or correct the error.

Reporting No Resolution. Seventeen percent of the 24 misread instances involved reporting that there was no resolution when there was one (according to the DART printout).

Incorrectly Assigning Maneuvers. In two (8% of the total) instances, the controllers assigned the maneuver to the wrong aircraft. For example, in a conflict between OPEC 34 and AAL 595, the controller read "Right 40 for OPEC 34" when the resolution was "Right 40 for AAL 595."

Miscellaneous. Finally, there was one case in which there were two successive conflicts that involved one of the same aircraft. A few seconds after there was a conflict between DYNAM 1 and COA 114, there was a conflict between DYNAM 1 and COA 258. The controller did not notice this change and thought that the new resolution was an update. The format for presentation of updates will change with CRAE.

Error analysis often points to display characteristics that induce them. In this case, however, no category of errors could easily be attributed to any specific aspect of the display. The types and frequency of misreads made by controllers during this test are an inevitable consequence of humans performing such tasks and must be expected to occur.

5. POST-TEST QUESTIONNAIRE RESULTS

After the test, controllers were given a questionnaire designed to elicit controller opinion on the CRA display and suggestions as to how the simulation could be improved.

5.1 CONTROLLER COMMENTS ON THE REALISM OF THE SIMULATION

The test controllers were asked to rate the realism of the communications, the communications equipment, and of the displays and controls used for the test on a scale of one to five. The anchors for "one", "three", and "five" were "very unrealistic", "moderately realistic", and "very realistic", respectively. The mean rating for the realism of the communications was 4.3. The mean rating for the realism of the communications equipment was 3.2, and the mean rating for the realism of the displays and controls was 4.5.

5.2 CONTROLLER COMMENTS ON CRA

In response to the question, **"Were the CRA messages presented in a format that was easily understood?,"** three out of the six controllers said "yes," two responded "no," and one said that it was clear as long as there was only one conflict present involving less than three aircraft.

In response to the question, **"Should the CRA message be displayed on the tabular list?,"** three of the six controllers responded "yes," one said "yes, but also on the data block," and two controllers responded "no." The follow-up question asked, **"If not, how should it be displayed?"** Of the two controllers who responded that the CRA resolution should not be displayed on the tabular list, one suggested that the maneuver be displayed graphically in a format similar to the present MSAW alerts, and the other controller was not sure how the resolutions should be presented.

During the test and in the questionnaire, controllers commented on the difficulties of having to look away from the conflict to read the tabular list. Focussing on the tabular list during a conflict not only went against what they were accustomed to doing, but also seemed attentionally taxing, as they then had to switch back to the traffic. As one controller noted, however, it is possible that some of these difficulties could be resolved with increased experience with CRA, particularly for new controllers who have fewer ingrained habits.

6. SUMMARY AND CONCLUSIONS

In Week 1 of the study it was found that the controllers' initial response to CRA was to resolve an impending conflict and then, if there was time, examine the CRA message. This response would be expected from controllers who have had no experience with CRA. Controllers who participated in Week 1 said that they occasionally used the CRA maneuver just to see what it would do. This would help to explain why the response times noted for Week 1 were longer than those noted for Week 2 (although the paucity of data points combined with the high variability in response times from Week 1 do not justify such a comparison).

Week 2 showed that when controllers use the CRA message, an average of 13 seconds could be expected to be required for the controller to read the CRA message and decide that it is usable.

A different use of CRA from that noted by controllers in Week 1 might be expected for controllers who have had previous experience with CRA. The confidence, or lack of confidence, that results from experience with the system will change the way controllers use CRA. Also, CRA may be used more when controllers have not anticipated a specific conflict, rather than when the conflict alert was expected and a maneuver already planned. Both the types of errors noted, and to a smaller extent the response times noted, would be expected to change (although not dramatically) with controller experience with the CRA function and display.

The application of the results of this study must be considered in the context of the computation of the delay parameter to be used in the CRA algorithm. The relevant component of this delay concerns the time lapse between the onset of the CRA message and the beginning of the pilot's response. Considerations of how much time will elapse between the time the CRA message appears and the time the pilot makes an input into the controls must include several factors. These factors include the controller's response time, the time required for successful transmission of a controller's message to the pilot and the pilot's response time.

The appropriate measure of controller response time is derived from the results of Week 2. To determine pilot response time, a study was conducted using voice tapes from ARTCCs (DOT/FAA/RD-91/20, August 1991). Pilot response time was combined with transmission time and measured from the beginning of the controller's transmission of a maneuver required for traffic avoidance to the end of the pilot's correct acknowledgement. The data from that study are summarized in Table 6-1 and Table 6-2. Personal communications with experts (such as the National Resource Specialist in Flight Management) and an informal pilot study supported our assumption that by the end of the verbal acknowledgement, the pilot will initiate an input into the controls (whether or not the pilot communicating is also the pilot flying).

TABLE 6-1. PILOT RESPONSE TIME (IN SECONDS)

Minimum	4.00
Maximum	40.00
Mean	10.85
Standard Deviation	5.91

Total Number of Observations = 80

TABLE 6-2. PILOT RESPONSE TIME (PERCENTILES)

5th	5.0
10th	6.0
50th	9.0
90th	17.0
95th	22.5

It is possible to add the mean or 90th percentile pilot response time (RT) to the mean or 90th percentile controller response time. However, a more appropriate statistical analysis considers all possible pairings of these two data sets and calculates the percentiles for the sum of the response times over all pairings. This method provides the best estimates available for the combined percentiles, assuming that the pilot and controller response times are independent. Table 6-3 presents these percentiles with the upper or lower confidence limits.

TABLE 6-3. COMBINED CONTROLLER/PILOT RESPONSE TIMES (IN SECONDS)

	Percentiles			
	5th	10th	90th	95th
Point Estimates (in seconds)	13	14	35	40
Confidence Limits:				
Lower .05	12	13.5	--	--
Lower .10	12.5	14	--	--
Upper .10	--	--	37.5	43
Upper .05	--	--	38.5	44

Mean Total Response Time = 23.57
95% Confidence Limits = (21.69, 25.45)
90% Confidence Limits = (22.00, 25.10)

Based on these data, it is recommended that 40 seconds be considered for the upper limit on the time expected to elapse between the onset of the CRA display and the time the pilot makes an input into the aircraft's controls.

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