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NASA Transport Systems Research Vehicle B-737 Data Link System and Display Formats

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SUMMARY

A data link system was designed to support flight tests in
the NASA Transport Systems Research Vehicle B-737 airplane.
The purpose of the flight tests was to evaluate pilot
acceptance of using data link as the primary source of
communications for strategic and tactical air traffic control
clearances, weather information, and company messages. This
report describes the airborne functional operations of the
data link system flight tested in 1990.

INTRODUCTION

Data link message exchanges for air traffic control offers
the potential benefits of increasing system safety and
efficiency by reducing communication errors and by enabling
more data to be exchanged between the aircraft and the ground
facilities. Digital communications between the air and
ground also present an opportunity to relieve the overloading
of air traffic control radio frequencies, which hampers
efficient message exchanges and flight operations during peak
traffic periods in many busy terminal areas.

A data link system for the NASA Transport Systems Research
Vehicle (TSRV) B-737 airplane and simulator was designed to
support research to determine pilot acceptance of using data
link as the primary communications system between the air and
the ground for the purposes of air traffic control, weather,
and company message exchanges.

The NASA airborne data link system and displays were designed
to be user friendly and to reduce flight crew workload. Menu
selectable information on overlapping windows for the data
link display formats were used to achieve user friendliness.
A touch panel mounted on the data link CRT display was
designed to keep keyboard activities at a minimum and
minimize crew workload.

Another system design for minimizing crew workload was the
ability of the crew to readily transfer data-linked
information into the airplane flight control system and/or
flight management system, It should be noted, however, that
information cannot be transferred into the airplane flight
control system or flight management system directly from the
ground; the flight crew must make the decision to transfer
the information and, with a single button push, cause the
information to be appropriately transferred.

This report describes the airborne operational functions of the data link system flight tested in the NASA TSRV B-737 airplane in 1990.

DEFINITIONS

ATC	Air traffic control
CDU	Control display unit
CRT	Cathode ray tube
FMS	Flight management system
RTE MOD REQ	Route modification request
TSRV	Transport systems research vehicle
TWEB	Transcribed weather broadcast
WCP	Weather communications processor
4D	Three dimensional path with time constraints

DATA LINK DISPLAY FORMATS

Window Format Sizes

The data link display formats are contained in three different sized windows that can overlay each other as shown in figure 1. The large window is 6.5" by 6.5" and is used to display the main menu page and the weather menu page. The medium size window is 5.5" wide and 4.5" high and is used to display all information composed by the flight crew to be data linked to the ground and for viewing stored messages and current ATC clearances. The small size window is 6.0" wide and 2.75" high and is used to display information sent from the ground to the airplane.

The data link windows are drawn on three layers. The small size window is always displayed on the top layer. It always has visual priority over the medium and the large windows. The medium window is always displayed on the middle layer and will overlay the large window. The large window is always displayed on the bottom layer and will not overlay any other window. The upper most layer displayed is the active window. Windows shown below the upper most layer are inactive.

Each window contains touch sensitive areas drawn as buttons. These buttons contain labels for annunciating various actions to be performed or format selections to be shown on the data link display. At the bottom of the large window, an area is used for message annunciation buttons to alert the crew of the arrival of non-time-critical messages. Touching these

areas results in appropriate messages, actions, or display formats to be shown.

Except for scroll buttons (buttons containing an arrow), the data link system interprets a button to have been pushed when the pilot's finger (or other touch device such as a pencil) is lifted from the button on the touch panel. If the pilot keeps touching the display, but slides his finger off of the button, no action as a result of touching the button will be taken by the data link system.

Scroll buttons contain arrows pointing up or down. Pushing a scroll button moves a message that can not be entirely seen on one window up or down so that the entire message may be read by the crew. Scroll buttons also increase or decrease numerical values generated by the flight crew during requests to ATC and during some requests for weather information. The scrolling action will continue as long as the pilot keeps touching the button.

Display Format Colors

The different colors used in the displays, as shown in figure 2, indicate the active and inactive windows, the currently touched button, and the touch target lines. The blue colored windows and buttons indicate that they are inactive, or dead. Touching blue buttons will not cause any actions to occur. The white colored windows and buttons are active. White buttons may be touched to cause an action to be taken by the data link system.

Two indications of where the pilot is touching the panel are shown by the magenta touch target lines and the green button. The magenta touch target lines cross the position on the touch panel that the airborne data link system interprets is being touched. If more than one touch is occurring simultaneously, the average position between all of the touches is computed as being touched and will be appropriately indicated by the touch target lines.

When the touch sensitive area inside a white colored (active) button is being touched, the color of that button is changed to green. This indicates to the pilot that if his finger is lifted from the touch panel from this point, the action appropriate for that button will occur. If the button is green but the pilot does not want that action to occur, he simply slides his finger off the button and the button will change from green back to white.

When the pilot lifts his finger from a green button, it will flash twice to indicate that their command has been accepted

by the data link system and then the appropriate action is being taken.

Ground to Air Messages

Non-time-critical messages are annunciated on buttons at the bottom of the large windows. In figure 3, non-time-critical messages from the weather communications processor (WCP), from ATC, and from the airline company (NASA in this example) are annunciated in the buttons on the lower part of the main menu page. The crew may respond to these message annunciations, in any order, by touching the appropriate button. This will result in that message being shown on a small size window that will overlay any previous large and/or medium windows shown. Once the crew responds to that message, the small window will disappear and the crew may select another non-time-critical message.

In figure 4, a time-critical message was data linked to the airplane by ATC. When a time-critical message is linked to the airplane, the message is displayed automatically in a small window. When a time-critical ATC message is displayed, an electronic digitized voice repeats the message to the flight crew. The flight crew must respond to that message before any other messages can be viewed or composed for down-linking to the ground.

With this time-critical message, the crew may respond by pushing the ROGER, ROGER/ENTER, or the UNABLE button. When the ROGER button is pushed, a "roger" message is sent back to ATC, the small window is removed, the message is stored for later inspection on the view message page, and appropriate message information is shown on the view clearance page. If the ROGER/ENTER button is pushed, the same actions occur as if the ROGER button was pushed and, in addition, appropriate commands will be inserted into the airplane flight control system and/or the flight management system. If the UNABLE button is pushed, an "unable" message is sent to ATC, the small window is removed, and the message is stored with an "unable" response for later inspection on the view message page

In figure 5, more than one time-critical message and numerous non-time-critical messages are waiting for a crew response. All time-critical messages must be responded to before the non-time-critical messages (buttons now shown in blue) may be observed. The crew may examine all of the time-critical messages by touching the TIME CRITICAL MESSAGE WAITING button on the top of the large window. When that button is pushed, the time-critical message displayed will be removed and the next time-critical message will be displayed. The crew may respond to the time-critical messages in any order desired.

Once the flight crew has responded to all the time-critical messages, the non-time-critical buttons are changed from blue to white colors so the crew can respond to them at their convenience.

Main Menu Page

From the main menu page shown in figure 6, the crew may select six display page options. The ATC page is used for constructing ATC related requests from the flight crew to ATC. The weather menu is used for constructing requests for weather information from a weather data base located on the ground. The ATIS page is used for requesting ATIS information. The NASA ground page is used for composing any free text (typed) messages to be sent to your own company. The view clearance page is used to view both your strategic (route) clearance and your current tactical (vectors, altitude, speed) clearances, and current ATC voice communications frequency that should be monitored. The view message page allows the crew to observe all ground-to-air and air-to-ground data linked messages that have occurred on their flight.

Data Link Page Format

A tree diagram of the possible pages that may be selected on the data link display is shown in figure 7. The display formats of each page are designed to lead the crew, in an obvious manner, through the tree so that crew requests may be readily constructed and sent to the ground.

ATC Request Menu Page

The ATC request menu page, shown in figure 8, allows the crew to construct requests to be sent to ATC.

Touching the CANCEL button removes all information constructed on this page and transfers the display back to the main menu page.

Touching the CLEAR button clears the last information constructed on this page, but keeps any previously constructed information and the ATC request menu page displayed.

Touching the SEND button causes the request constructed to be sent to the ground.

Touching the CLEARANCE button causes the request for a strategic (route) clearance to be constructed on the data

link display. Then, touching the SEND button causes the
clearance request to be sent to ATC. This clearance is
normally requested before starting the flight. When a reply
to this request is transmitted from ATC to the airplane, the
clearance is displayed on the small window. The crew may
then automatically enter the entire route into the flight
management system by touching the ROGER/ENTER button.

Touching the PROFILE button causes the location of the top of
descent point and the speed profile used during the descent
to be copied from the flight management system. The crew may
then send that information to ATC.

In figure 9, touching the route modification request (RTE MOD
REQ) button causes a modified route in the flight management
system, if one exists, to be copied to the data link system.
This route modification is then shown on the data link medium
size window in the format necessary for transmission to ATC
as shown in figure 10. The crew may then send that request
for a new route by touching the SEND button. If a modified
route does not exist in the FMS, the current active route
will be copied to the data link system.

When the ATC request menu page is initially brought to the
display, the current altitude, heading, and airspeed of the
airplane is shown in the respective buttons as shown in
figure 11. These buttons may be touched one at a time to
construct a request for a new heading, altitude, and/or
airspeed as follows. The crew touches one of the buttons
(airspeed as shown in figure 11). Another medium size page
is displayed, as shown in figure 12, with the current
airspeed of the airplane shown. The crew may adjust that
airspeed figure by touching either of the scroll keys (up or
down arrow buttons). If the scroll key is continuously
touched, the airspeed will continue to be incrementally
changed. In this example, the crew adjusted the speed to 250
knots. The crew would then touch the OK button and the
display window would be changed back to the ATC request menu
page with the airspeed button changed to blue (inactive key).

In figure 13, the crew has constructed a request for an
altitude of FL270, a heading of 200 degrees, and an airspeed
of 250 knots. When the crew is satisfied with the
construction of their request, the SEND button would be
pushed and the request sent to ATC.

ATIS Request Page

Touching the ATIS button on the main menu page causes the
ATIS request page to be displayed on a medium size window, as
shown in figure 14. The airport name that is automatically
shown on the ATIS request page is the origin airport

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programmed in the FMS when the airplane is on the ground and
the destination airport when in the air.

If the ATIS from another airport is desired, the crew would
touch the CLEAR/CDU button. This would result in pilot-
inputs from the keyboard of the FMS CDU being sent to the
data link system so the crew could type the airport
identifier name. When the SEND or the CANCEL button on the
data link window is touched, pilot-inputs through the CDU
keyboard would be sent to the FMC.

When the SEND button is touched, the ATIS request for the
airport identifier shown in the middle of the ATIS window is
sent to ATC. If the CANCEL button is touched, the ATIS
request page is removed from the display and replaced with
the main menu page.

View Messages Page

Touching the VIEW MESSAGES button on the main menu page
causes the view messages page to be displayed on a medium
size window, as shown in figure 15. The message list shown
contains who sent each message and when (time) the message
was sent on the data link. If it was a message transmitted
from the ground to the airplane, the view message page also
contains when the message was received by the airplane, when
the crew answered or responded, and the type of response--
ROGER, ROGER/ENTER, or UNABLE--to the message.

The messages are listed in the order of the time that they
are transmitted to the air or the ground. The message list
may be scrolled up or down by touching the scroll buttons.

If the airplane is on the ground, the crew may erase the
message list by touching the CLEAR button. This will cause a
message to be shown inquiring if the list is really to be
erased. If it is to be erased, the crew touches the CLEAR
button again. If it is not to be erased, the crew touches
any other button and the view messages page is shown again.
The messages may not be erased unless the airplane is on the
ground.

Touching the MAIN MENU button will remove the view messages
page and show the main menu page.

View Clearance Page

Touching the VIEW CLEARANCE button on the main menu page
causes the view clearance page to be displayed on a medium
size window, as shown in figure 16. The top of that page
shows the current ATC strategic (route) clearance. Below

that clearance is a list of the current tactical clearances
(heading, altitude, speed, metering fix time for 4D
operations) and the voice communications frequency and ATC
facility name the crew has been assigned to monitor.

Touching the MAIN MENU button causes a return to the main
menu page.

Weather Menu Page

From the weather menu page, shown in figure 17, the crew may
select eight weather display page options, or, return to the
main menu. The weather page is used for constructing weather
related requests from an aviation weather data base located
on the ground. When touching the transcribed weather
broadcast (TWEB) button on the weather menu, a request for a
route code will automatically be requested. The crew will
then have to type the TWEB route code on the data link
display through the CDU keyboard to obtain weather
information along specific routes.

When the SIGMET/AIRMET button is touched on the weather menu,
a request for the name of the state in which the information
is desired will automatically be requested. The crew will
then have to type the name of the state on the data link
display through the CDU keyboard to obtain the SIGMET/AIRMET
information.

Touching the MAIN MENU button will cause the data link
display to be changed back to the main menu page format.

Touching any of the other buttons on the weather menu page
(except TWEB, MAIN MENU, or SIGMET/AIRMET), will result in
the question of location for the weather information request.
Location, while on the ground, is the origin airport
programmed in the FMS. While in the air, location is the
destination airport. If neither of these airports are the
desired location for the weather request, then the crew may
select the CLEAR/CDU button (figure 18).

Figure 18 shows an example where the crew is constructing a
request for the terminal forecast for Wallops airport (WAL).
Touching the SEND button will send the request to the ground,
remove the terminal forecast request window, and show the
weather menu window. If some other airport besides WAL was
desired, then the crew would have touched the CLEAR/CDU
button and typed the airport identifier on the CDU keyboard.

Figure 19--22 show an example of the pages necessary to
request winds and temperatures aloft. When the WINDS TEMP
button is touched on the weather menu, the destination
airport is displayed as shown in figure 19. If the crew
wishes to change that airport name, they may do so through

the CDU keyboard (touching the CLEAR/CDU button and then
typing the identifier). When the location is satisfactory to
the crew, the OK button is touched and the desired altitude
is requested next.

Figure 20 shows that the present altitude of the airplane is
inserted in the winds aloft forecast request page. Any other
altitude may be inserted by touching either of the scroll
buttons. When the desired altitude is shown on the window,
the crew touches the OK button and the time for the forecast
will be requested as the number of hours from the present
time (figure 21). The number of hours from now may be
adjusted with the scroll buttons. When the time is selected,
the crew touches the OK button and the scroll buttons will be
replaced with the SEND button (figure 22). The crew may now
send the request by touching the SEND button.

LARGE WINDOW (6.5" X 6.5")

0.75"

MEDIUM WINDOW (5.5" X 4.5")

1.25"

SMALL WINDOW (6.0" X 2.75")

TOUCH SENSITIVE AREAS

1.5" X 0.75"

MESSAGE ANNUNCIATION AREAS
(TOUCH SENSITIVE)
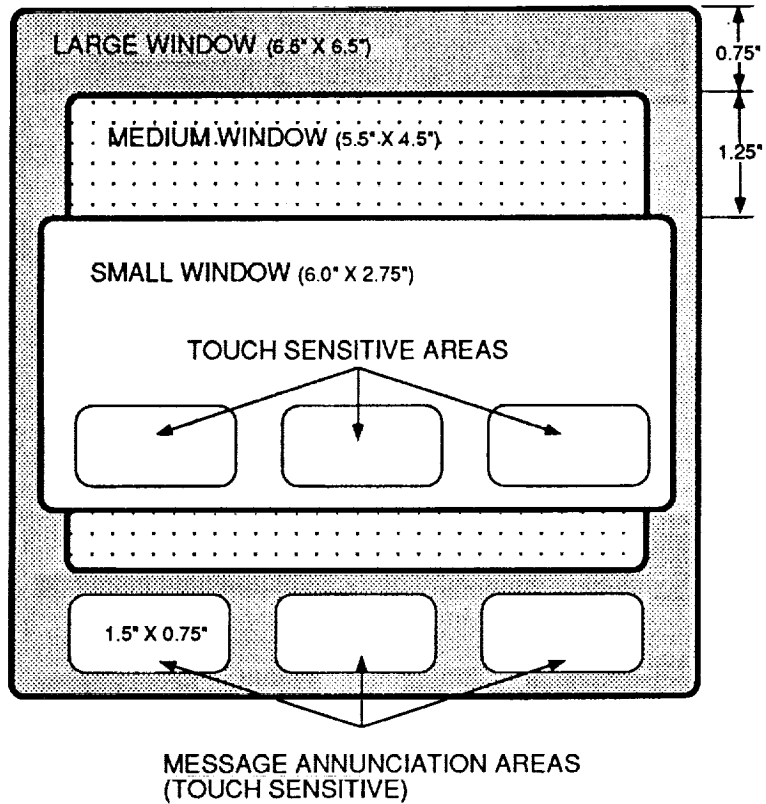
Figure 1.--Data link window format sizes.

INACTIVE DISPLAY
HAS BLUE
LETTERS/LINES
WITH BLACK
BACKGROUND.

MAIN MENU

ATC 164200:
TURN LEFT TO 350. DESCEND AND MAINTAIN 27
THOUSAND.

ACTIVE DISPLAY
HAS WHITE
LETTERS/LINES
WITH BLACK
BACKGROUND.

GREEN

ROGER

ROGER
ENTER

UNABLE

MAGENTA
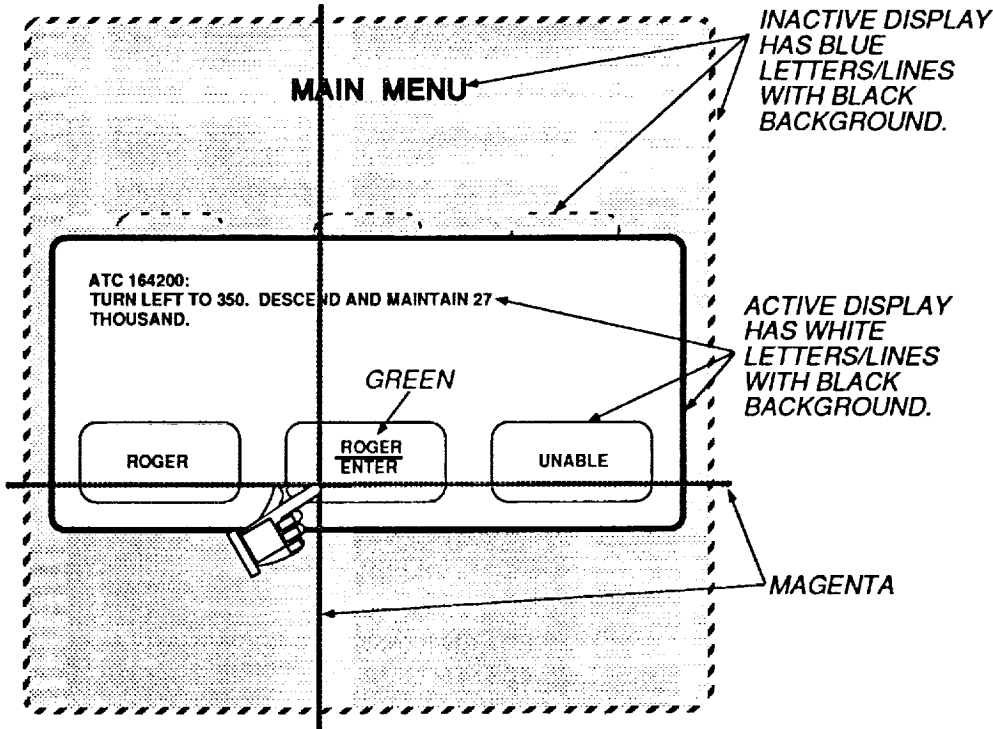
Figure 2.--Data link display colors.

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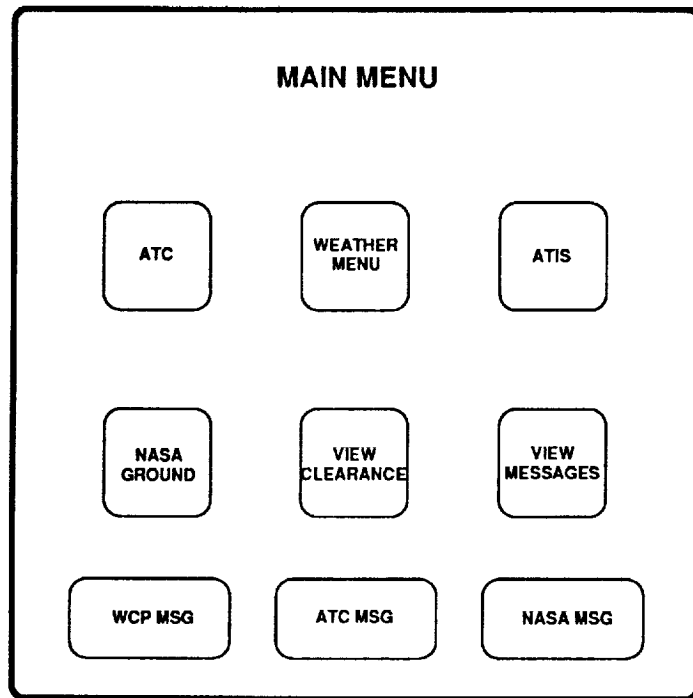
Figure 3.--Non-time-critical messages overlay.
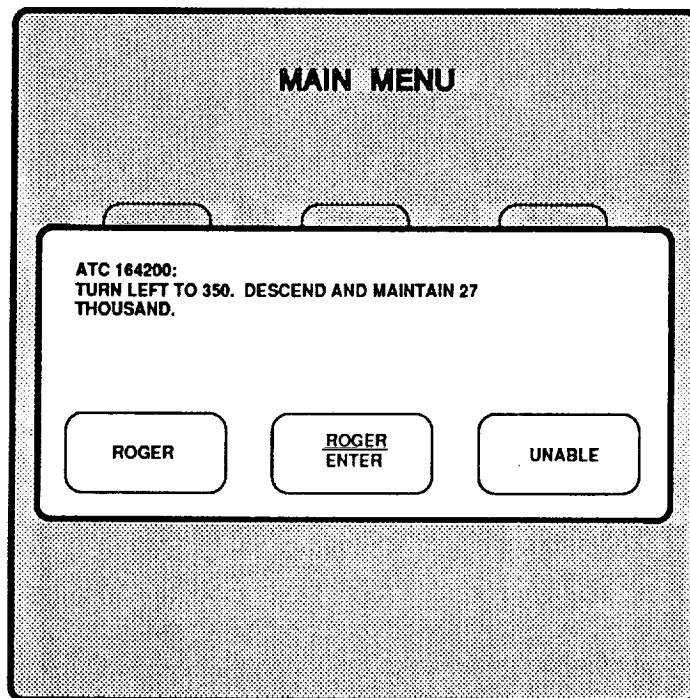
Figure 4.--Time-critcial message overlay.
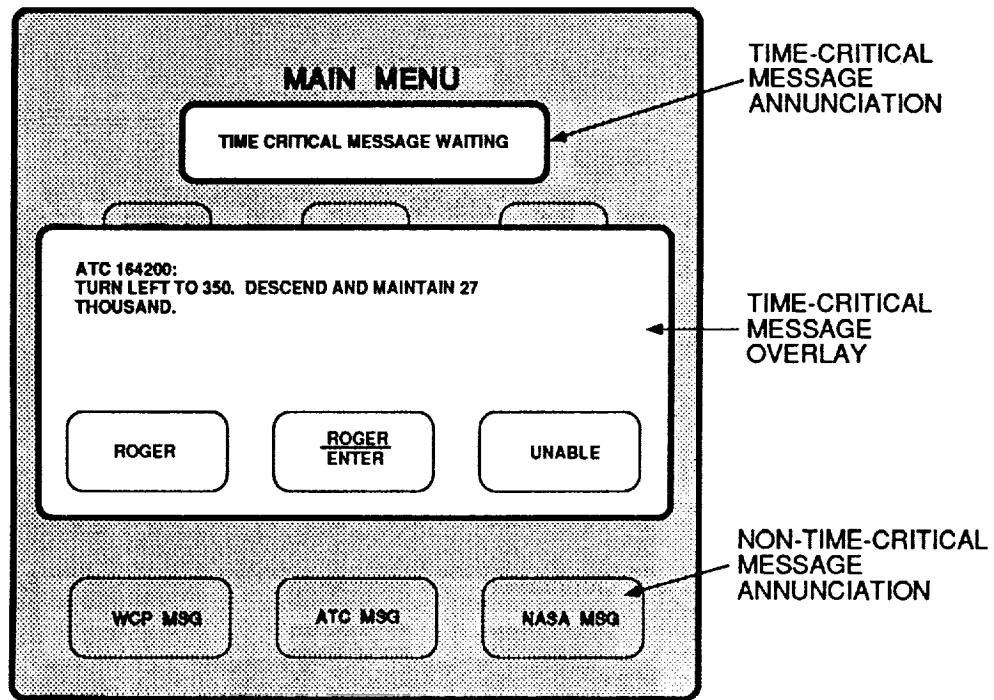
Figure 5.--Multiple time-critical and non-time-critical messages overlay.
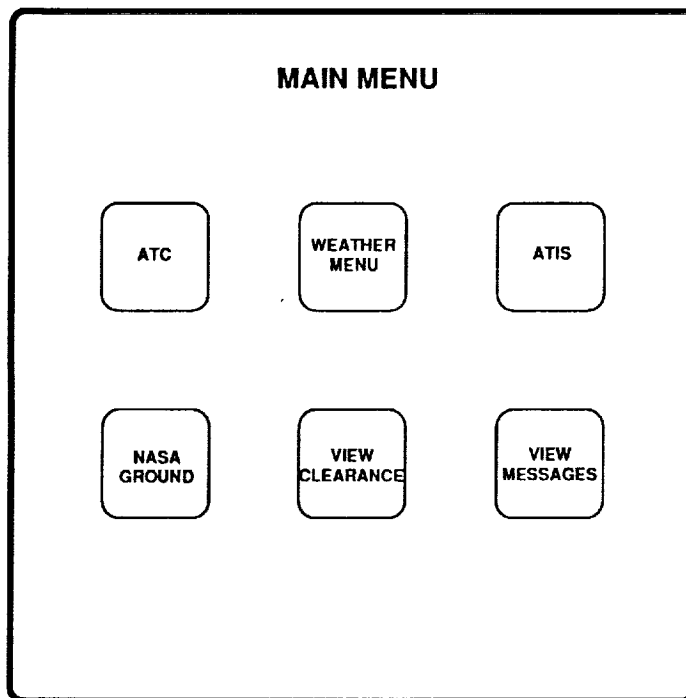
Figure 6.--Main menu page format.
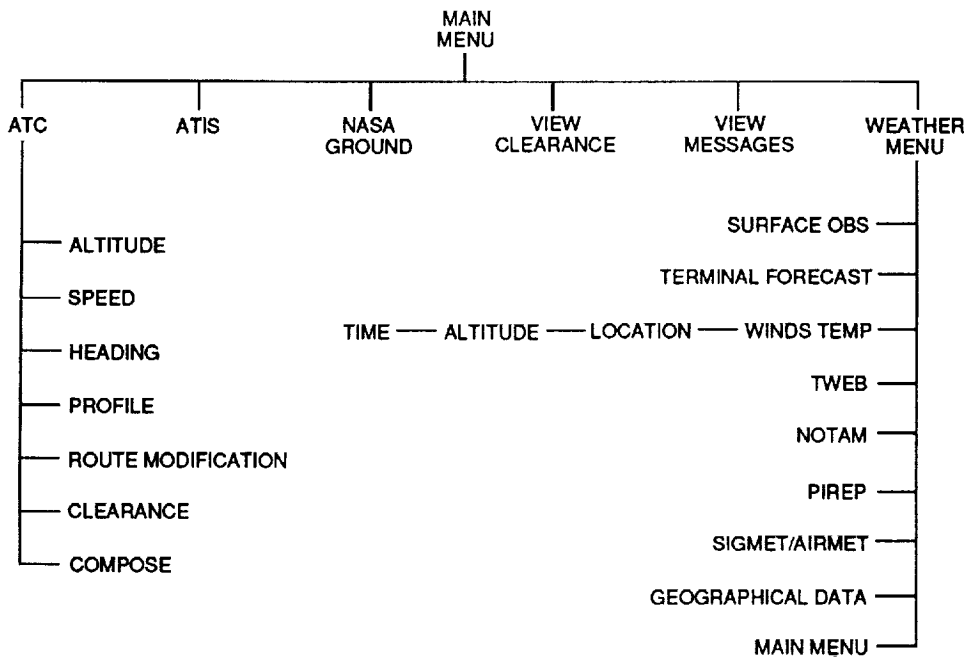
Figure 7.--Data link page format tree.
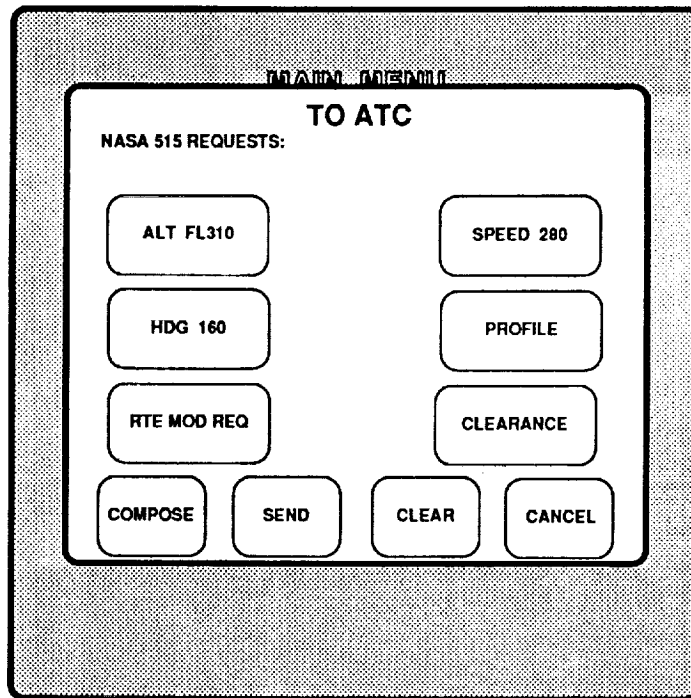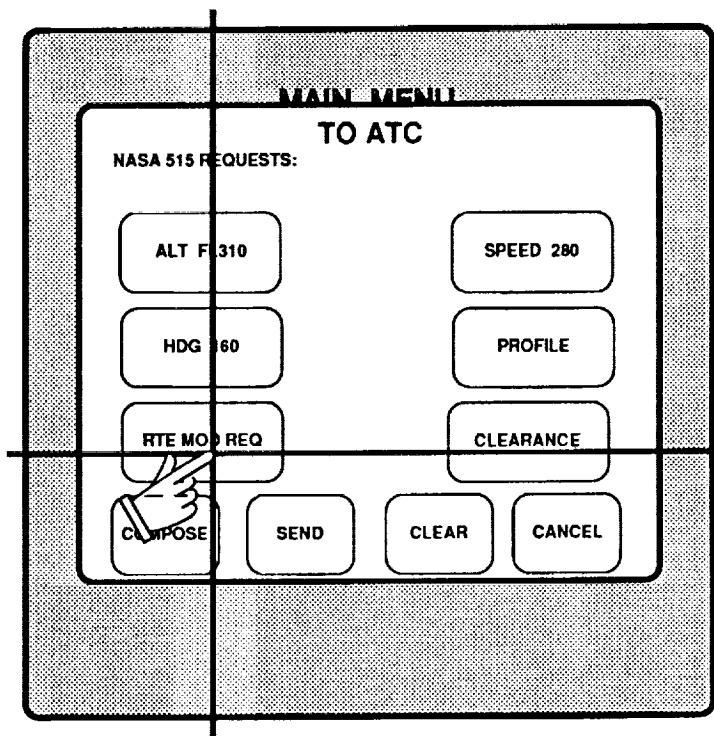

Figure 8.--ATC request menu page format.

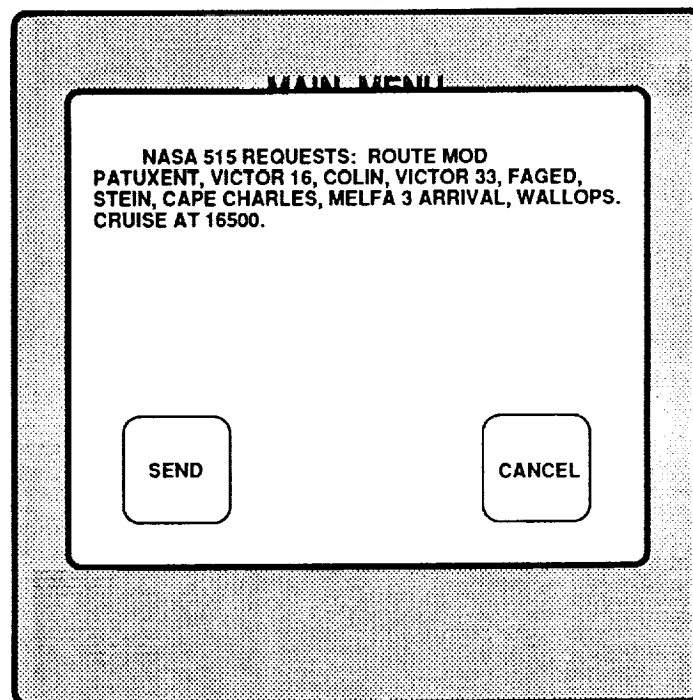Figure 9.--Route modification request on the ATC request menu page.
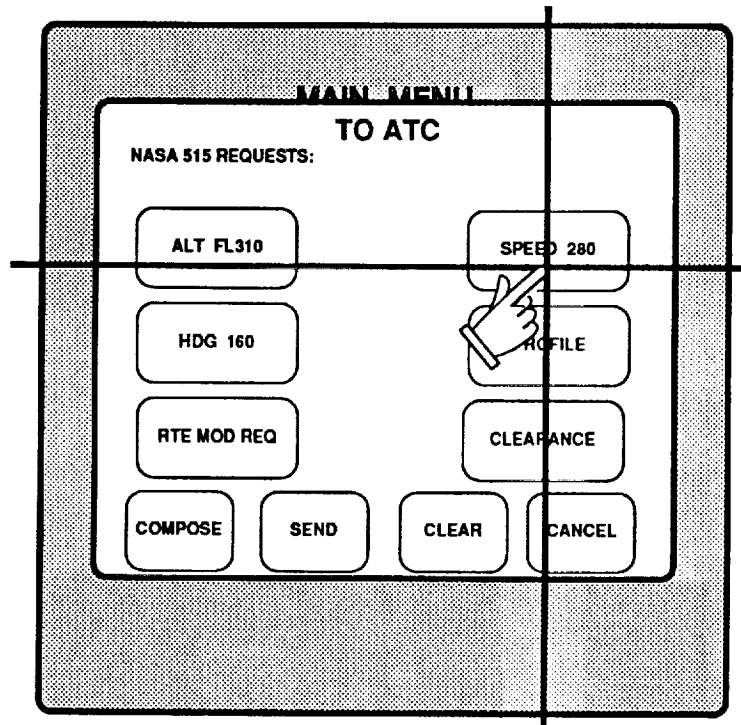

Figure 10.--ATC route modification request page.

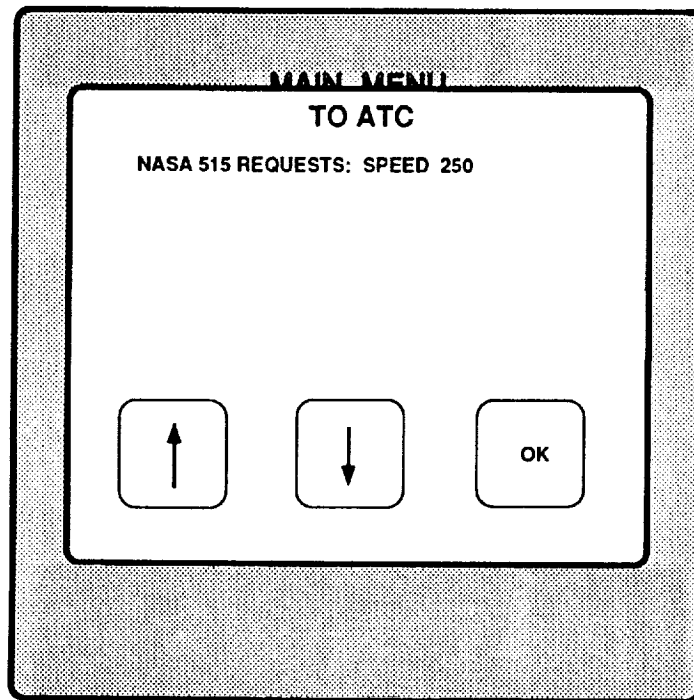Figure 11.--Airspeed request on ATC request menu page.
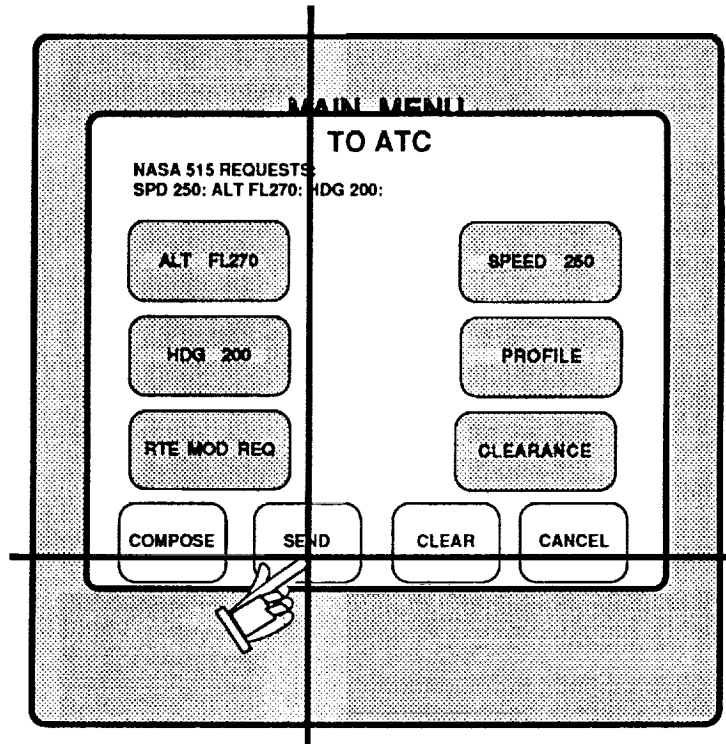

Figure 12.--ATC airspeed request page format.

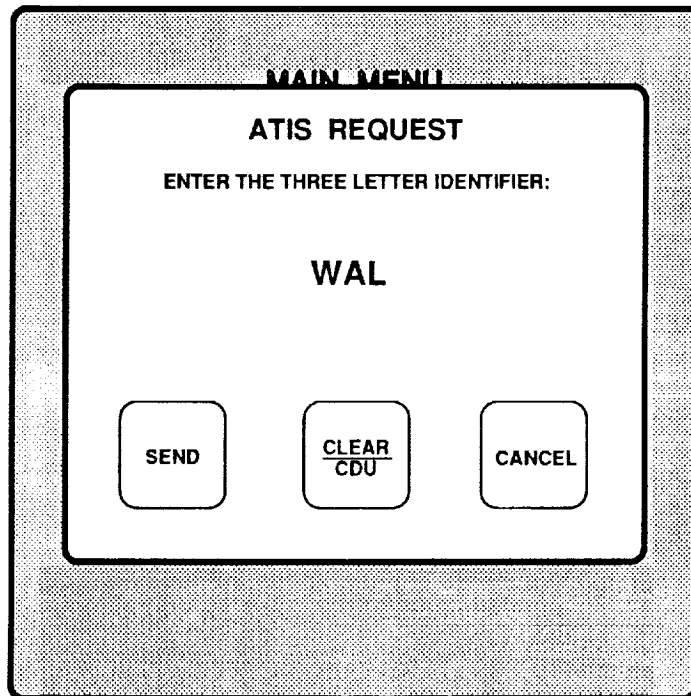Figure 13.--Requests sent to ATC from the ATC request menu page.
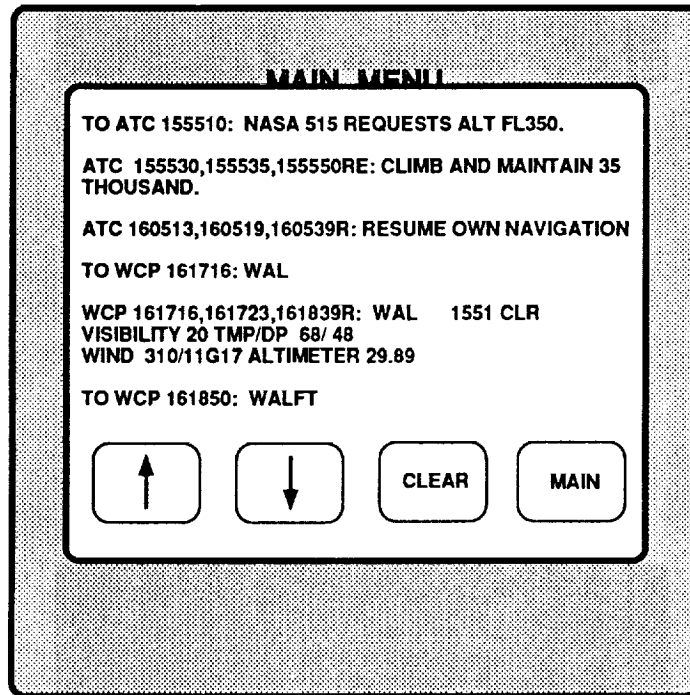

Figure 14.--ATIS request page format.

MAIN MENU

TO ATC 155510: NASA 515 REQUESTS ALT FL350.

ATC 155530,155535,155550RE: CLIMB AND MAINTAIN 35
THOUSAND.

ATC 160513,160519,160539R: RESUME OWN NAVIGATION

TO WCP 161716: WAL

WCP 161716,161723,161839R: WAL   1551 CLR
VISIBILITY 20 TMP/DP 68/ 48
WIND 310/11G17 ALTIMETER 29.89

TO WCP 161850: WALFT

| ↑ | ↓ | CLEAR | MAIN |

Figure 15.--View messages page format.

MAIN MENU

CURRENT CLEARANCE:
KWAL.D-W2MFV.JAMIE.STEIN.FAGED.COLIN.V213.ENO.
ATR.S-IL2ATR.KWAL:EA165:SQ4545:DF23450:

CURRENT ASSIGNMENTS:

ALTITUDE: 08500
HEADING: 2500
SPEED: 210
MF TIME: ----------
VOICE FREQ: 123.550   WAL APR

MAIN
MENU
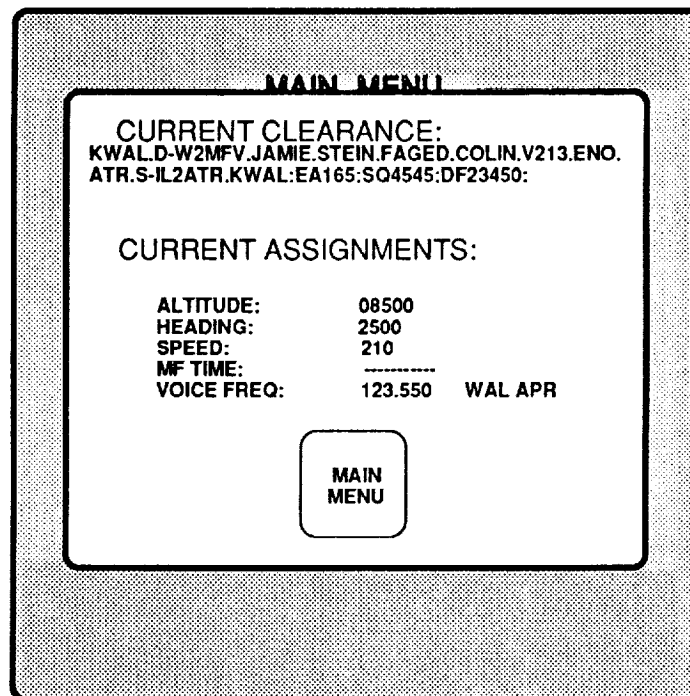
Figure 16.--View clearance page format.

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WEATHER MENU

SURFACE OBS	TERMINAL FORECAST	WINDS TEMP
TWEB	NOTAM	PIREP
SIGMET AIRMET	GEOG DATA	MAIN MENU
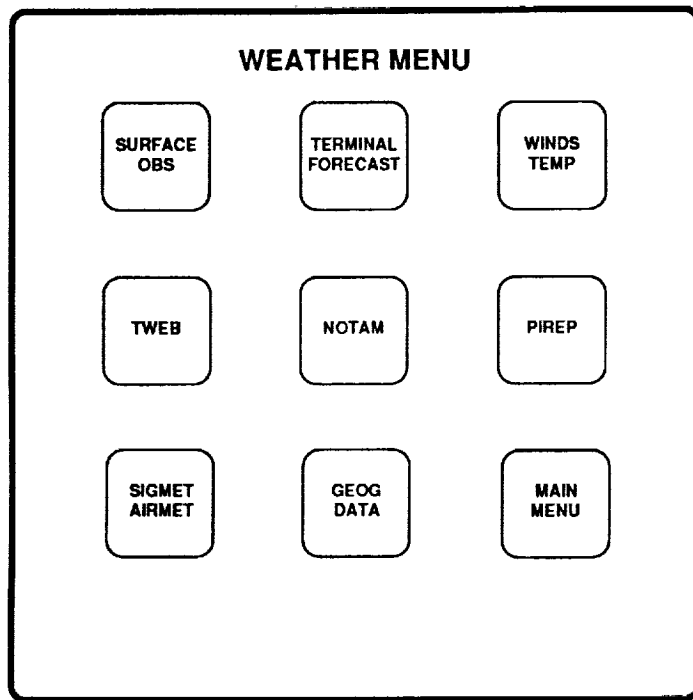
Figure 17.--Weather menu page format.

WEATHER MENU

TERMINAL FORECAST REQUEST

ENTER THE THREE LETTER IDENTIFIER:

WAL

SEND	CLEAR CDU	CANCEL
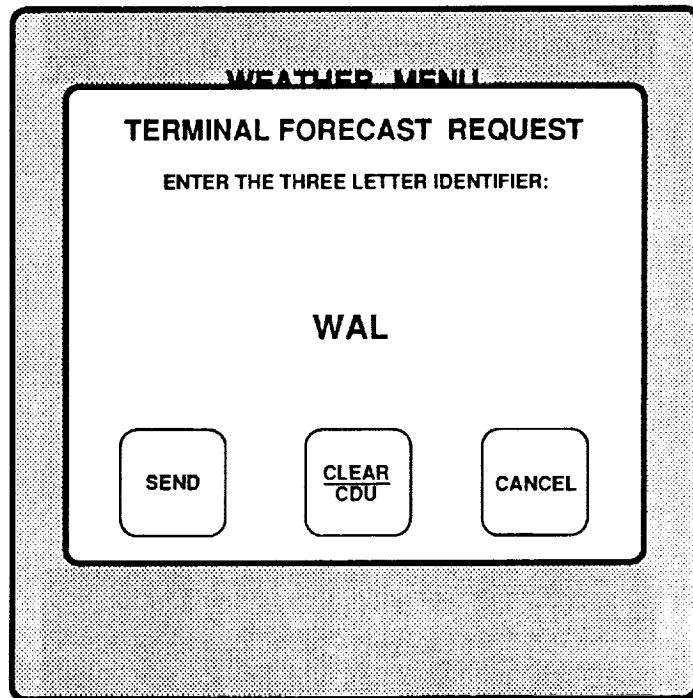
Figure 18.--Weather forecast request page.

WINDS ALOFT FORECAST REQUEST

ENTER THE THREE LETTER IDENTIFIER:

WAL

OK   CLEAR CDU   CANCEL

Figure 19.--Winds aloft request page 1 format.

WINDS ALOFT FORECAST REQUEST

IDENTIFIER: WAL
ALTITUDE: 33000
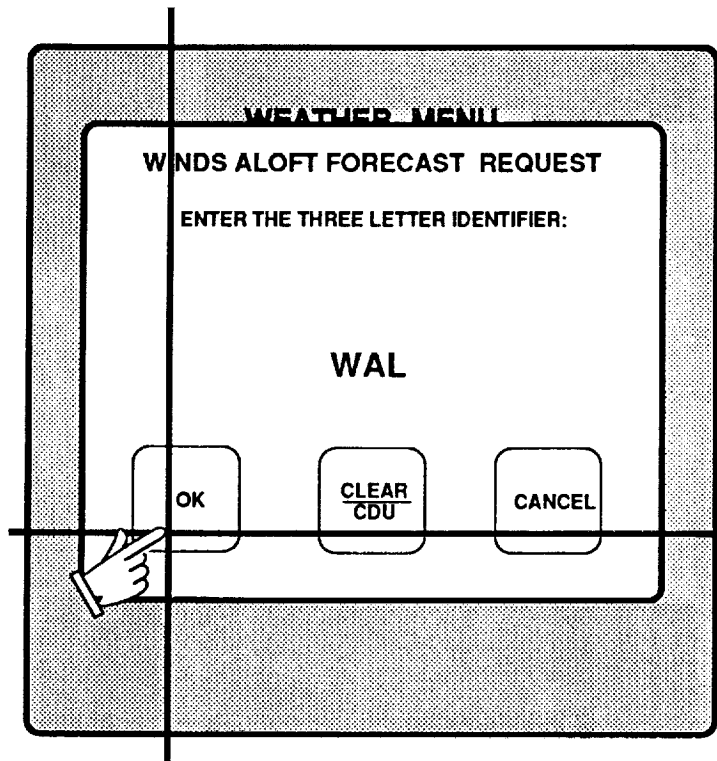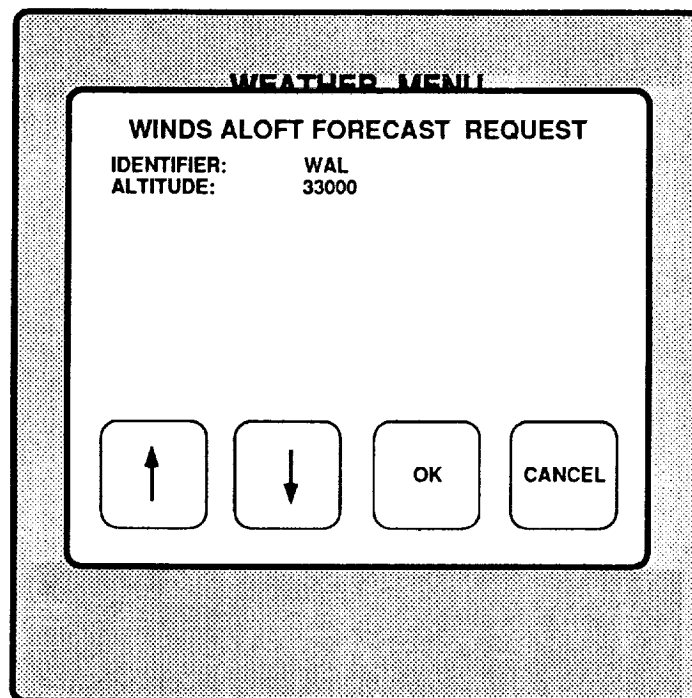
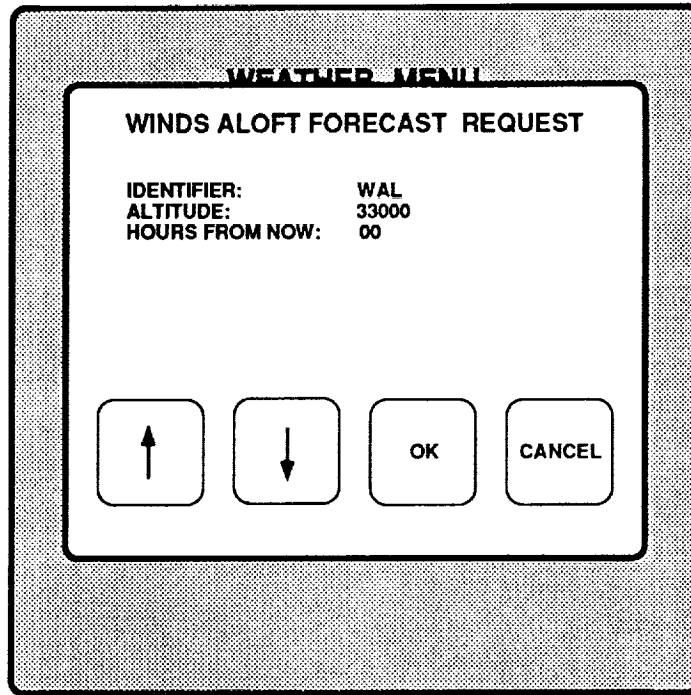↑   ↓   OK   CANCEL

Figure 20.--Winds aloft request page 2 format.

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Figure 21.--Winds aloft request page 3 format.

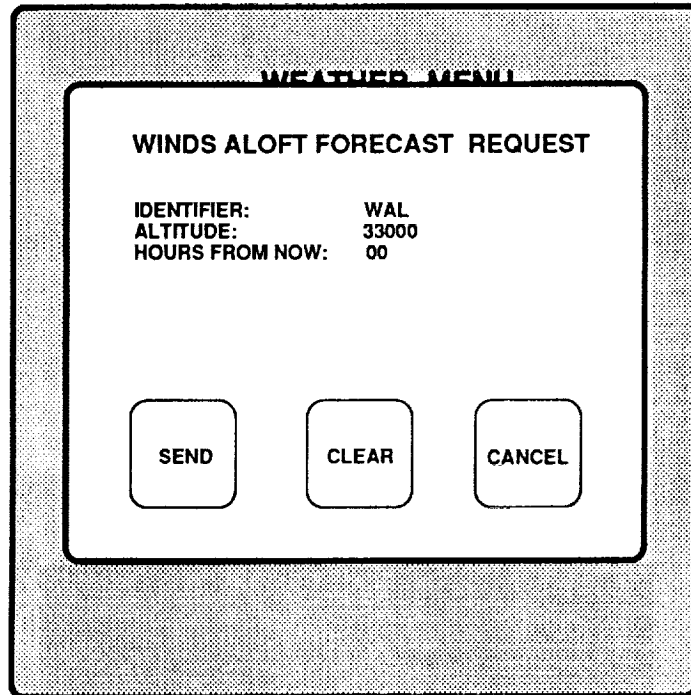Figure 22.--Winds aloft request page 4 format.

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15. Supplementary Notes

16. Abstract

A data link system was designed to support flight tests in the NASA Transport Systems Research Vehicle B-737 airplane. The purpose of the flight tests was to evaluate pilot acceptance of using data link as the primary source of communications for strategic and tactical air traffic control clearances, weather information, and company messages. This report describes the airborne functional operations of the data link system flight tested in 1990.

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