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CONTROLLER AND COMPUTER DISPLAY INTERFACE IN AN ADVANCED TERMINAL AREA ATC SYSTEM

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ABSTRACT

Controller and display interactions and information requirements in an advanced Air Traffic Control (ATC) system are investigated. A description of the present ATC system and of some proposed developments for the future is presented. Suggestions are made for interfacing and modifying these present system concepts for implementation in an advanced system. Emphasis is on tower controllers and their display/data entry requirements (using the Terminal Information Processing System, TIPS).

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TABLE OF CONTENTS

Section No.		Page No.
	LIST OF FIGURES	8
I	INTRODUCTION	9
	1.0 Introduction	9
II	BACKGROUND	11
	2.0 The Present System	12
	2.1 General Description	12
	2.2 Tower Positions	15
	3.0 The Next Step in Tower Automation: Terminal Information Processing System (TIPS)	18
	3.1 TIPS General Description	18
	3.1.1 Introduction	18
	3.1.2 Display Description	19
	3.2 TIPS Description by Controller Pos.	24
	3.2.1 Ground Control	24
	3.2.2 Local Control	30
	3.2.3 Clearance Delivery	33
	3.2.4 Flight Data	35
	4.0 Other Systems Under Development	36
	4.1 Discrete Address Beacon System (DABS)	36
	4.2 Enhanced Terminal Information Service (ETIS)	40
	4.2.1 Background: ATIS	40
	4.2.2 ETIS Features	41
	4.2.3 Message Types	42
	4.3 Airport Surface Traffic Control (ASTC)	45
	4.4 Air Traffic Management and Control Automation (ATM/C)	47

TABLE OF CONTENTS Condt. Page No.

4.4.1 General Description..... 47
4.4.2 Ground Control System..... 48
4.4.3 Interfaces..... 51

III AN ADVANCED ATC SYSTEM: REQUIREMENTS AND SUGGESTED MODIFICATIONS..... 53

5.0 General..... 55

5.1 Controller Inputs..... 55
5.2 Command Display..... 55
5.3 Pilot Response..... 56
5.4 Alerts..... 58
5.5 Flagging..... 59
5.6 Avionics Capability..... 59
5.7 Command Validation and Relay..... 61
5.8 Reconfiguration of Active Runways..... 63
5.9 TIPS List Display Requirements..... 64
5.10 ATM/C Information Requirements..... 64

6.0 Traffic Control Functions..... 67

6.1 Air Traffic Management and Control... 67
6.1.1 Handoffs..... 67
6.1.2 Missed Approach..... 68
6.1.3 Landing Clearance..... 69
6.1.4 Take-off Clearance..... 70
6.1.5 Schedule Information..... 71

6.2 Surface Traffic Control..... 72

6.2.1 Gate Hold Procedures..... 72
6.2.2 Gare Assignments..... 74

7.0 Flight Data Functions..... 75

8.0 ETIS Functions..... 77

8.1 Display Requirements..... 77
8.2 Alerts and Notifications..... 79
8.3 Manually Entered Data..... 80
8.4 Automated Data Relay..... 81

1V FINAL DISCUSSION..... 83

9.0 Areas for Further Work..... 83

10.0 Summary 84

TABLE OF CONTENTS Contd.

Page No.

10.1 Suggested TIPS Modifications and Enhancements..... 85

10.1.1 Display Requirements..... 86
10.1.2 Functions and Capabilities..... 87

V REFERENCES..... 89

VI APPENDICES..... 92

App. A: Present Controller Requirements for Tower and TRACON Positions..... 93

A.1 Tower Positions..... 94

A.1.1 Ground Control (GC)..... 94
A.1.2 Local Control (LC)..... 97
A.1.3 Clearance Delivery (CD).....102
A.1.4 Flight Data (FD).....104
A.1.5 Cab Coordinator (CC).....105
A.1.6 Team Supervisor (TS).....108

A.2 TRACON Positions.....111

A.2.1 Arrival Radar (AR).....111
A.2.2 Departure Radar (DR).....114
A.2.3 Final Control (FC).....116
A.2.4 Terminal Control (TC).....118
A.2.5 Departure Data (DD).....120
A.2.6 Arrival Data (AD).....122
A.2.7 TRACON Coordinator(CI).....124
A.2.8 TRACON Supervisor (TR).....125

App. B: TIPS.....127

B.1 Operation of the Quick Action Data Entry Unit.....127

B.2 TIPS Functions.....130

B.2.1 General Inputs.....130
B.2.2 Quick Action Functions.....131

TABLE OF CONTENTS Contd. Page No.

B.2.2.1 Common to Tower Positions.....131
B.2.2.2 Ground Control.....133
B.2.2.3 Local Control.....136
B.2.2.4 Clearance Delivery..138
B.2.2.5 Flight Data.....138

Appendix C: Command Message Formats and Examples.....139

LIST OF FIGURES

Page No.

1 TIPS Display/Data Entry Unit..... 21

2 TIPS Display Presentation Format..... 22

3 TIPS Quick Action Hand Control..... 25

4 TIPS Keyboard..... 26

5 Example TIPS Display Presentation for Ground Control. 28

6 Example TIPS Display Presentation for Local Control.. 31

7 Example TIPS Display Presentation for Clearance Delivery..... 34

8 The ATM/C Ground Control System..... 49

9 Typical ETIS Message..... 78

B.1 TIPS Quick Action Data Entry Unit and Its Operation..128

I. INTRODUCTION

1.0 Introduction

Air traffic control (ATC) is an evolutionary process. Elements of the system are designed for augmentation; new features are introduced as they become feasible. Since safety is the prime concern of the ATC system, changes come about slowly. Once a modification becomes technically possible, there are many years of lab and field testing before widespread implementation takes place.

As the system changes, so do the duties and requirements of the controllers. A consequence of ATC evolution is increased automation. The level of automation has grown over time; most of the systems now under development or planned for the future will offer further enhancements. Inherent in automation is increased controller interaction with computers. Computers have allowed routine controller tasks to be done automatically or to be simplified. In the future, controllers will be further aided by machines. A large amount of information will be available on display or by call-up. Computers will assist controllers by not only stating problems, but by offering solutions (and facilitating intercontroller coordination).

The advanced ATC system concept considered in this study will contain elements that are presently being developed. Since none of these system components have been implemented yet, their proposed functions and capabilities are assumed. The purpose of this thesis is to investigate controller and system interface/interaction in an advanced ATC environment. It is a preliminary examiniation, intended to focus attention on matters that will be of interest as these systems are introduced. Suggestions are made as to possible controller duties and tasks, and to modifications of the system concepts. Emphasis is placed on tower controllers and their display/data entry requirements. A description of the present ATC system and controller responsibilities is also presented.

There are areas of study beyond the scope of this effort which will be addressed after more development and testing is completed on the system components. The feasibility of the interface suggestions will need to be determined. Human factor considerations are of prime importance, controller and pilot workloads must be resolved. Controller acceptance of changes in tasks and duties will also need to be examined.

II. BACKGROUND

Sections II contains information regarding some systems now under development. It is assumed in this thesis that they will be part of an advanced ATC system in the future. Descriptions are given in Section II to provide the background to discuss purposes, modifications and interface requirements in Section III.

Emphasis is placed on TIPS. Its display/data entry capabilities will change many of the present controller functions. TIPS may serve as an interface "hub" for some of the other system. There is also a definitive concept of TIPS available since a working model is presently being constructed.

2.0 The Present System

2.1 General Description

Control responsibilities are divided among 3 facilities:

1) Air Route Traffic Control Centers (ARTCC) - control aircraft in the airspace between terminal areas

2) Terminal Radar Control Facility (TRACON) - handles all aircraft within the Terminal Control Area (TCA) except for those controlled by the tower. (The TCA extends to about 40 miles from the airport and to an altitude of around 14,000 feet.)

3) Tower - responsible for arriving and departing aircraft on the airport surface or in its vicinity (to about 5 miles)

The tower and TRACON are usually co-located at a major airport. ARTCC's are distributed across the U.S.

The basic source of information to TRACON and ARTCC controllers is the automated Radar Tracking System (ARTS). ARTS III is the system used at over 60 major terminal areas within the U.S. It provides automatic identification and tracking of transponder equipped aircraft. Alphanumeric

displays of identification, aircraft type, ground-speed and altitude can be provided (in data blocks) for each aircraft on the controller's radar screen. There is also the capability for semi-automated radar handoffs of aircraft between controllers, requiring a minimum number of actions.

The primary method of determining aircraft position by tower controllers is through visual observation. (The local controller is provided with ARTS information on a BRITE display. He uses it mainly to aid in specifying the identification of arriving aircraft.)

All communication with aircraft is via voice radio channel. Communication within a facility can be done verbally by intercom or face-to-face. Exchanges between facilities is done by intercom (tower-TRACON), phone or teletype.

Flight plan data is provided to controllers on flight strips. All IFR (instrument flight rule) flights have to be filed in advance with the National Airspace System (NAS). This information is then provided to the appropriate facility by the Flight Data Entry and Printout (FDEP) subsystem. Tower and TRACON personnel handwrite flight strips for arriving and departing VFR (visual flight rule) flights.

They also denote data changes or significant information by marking the strip. Flight strips must be distributed to the controllers. (In some instances, tower controllers use the passing of flight strips to indicate handoffs.) Flight strips can contain the following information:

Arrivals & Departures:
- Aircraft identification (ACID)
- Aircraft type
- Computer I.D.
- Beacon code

Arrivals:
- Previous fix
- Coordination fix
- Estimated Time of Arrival (ETA) at the coordination fix
- Destination airport

Departures:
- Proposed departure time (PDT)
- Requested Altitude
- Departure Airport
- Route

Controllers are provided with weather and status information (i.e., runways in use, wind, visibility, etc.) for aid in control duties and for relay to the pilots. Some of this information is tape recorded by a tower controller for inclusion in Automated Terminal Information Service (ATIS) broadcasts. Pilots tune into the ATIS

frequency whenever they want its information. ATIS is updated approximately once an hour. See (section 4.2.1 for more on ATIS and the specific information contained it it.)

2.2 Tower Positions

A clearer picture of the present system can be gotten from a functional description of each controller position. A brief presentation of the tower positions is contained below. A more detailed account of tower and TRACON controller duties, tasks and available equipment is given in Appendix A.

2.2.1 Clearance Delivery (CD):

CD transmits clearances for departing aircraft and ensures that all aircraft have current ATIS information. He coordinates with Departure Control on aircraft not represented in the NAS and also assists Flight Data when necessary.

2.2.2 Flight Data (FD):

FD is responsible for all FDEP and ARTS III activity required in the tower (i.e., flight strip preparation, ARTS

keyboard entries, etc.) He receives and verifies clearances from ARTCC or other ATC facilities. FD performs many of the tower 'housekeeping' duties (i.e., changing the roll in the teletype, compiling statistics, etc.). He has no direct communication to aircraft.

2.2.3 Ground Control (GC):

GC is responsible for routing all surface traffic (aircraft and ground vehicles) on the airport except for that on active runways. He provides information and advisories to departing aircraft as needed.

2.2.4 Local Control (LC):

LC handles arriving and departing aircraft in the vicinity of the airport and on active runways. He is responsible for maintaining separation standards and for checking weather and clearance. LC recommends to the Team Supervisor the selection of active runways, and also works closely with the Cab Coordinator.

2.2.5 Cab Coordinator (CC):

CC works with LC, but with other tower controllers when required. He coordinates tower activities with the

TRACON. CC maintains close surveillance of inbound traffic and determines runway usage. His major responsibility lies with arrivals, as compared to LC who must divide his attention among arrivals and departures. CC has no direct communication with the aircraft.

2.2.6 Team Supervisor (TS):

TS directs the overall activity of the tower. He makes final decisions and provides assistance in operational situations. CC monitors operating status of equipment and communicates with outside agencies (i.e., the fire department, Coast Guard, etc.). CC is also responsible for the accuracy of ATIS information (makes the tape recording).

3.0 The Next Step in Tower Automation: The Terminal Information Processing System (TIPS)

3.1 TIPS General Description

3.1.1 Introduction

The current system used to communicate flight plan information, the Flight Data Entry and Printout system (FDEP), has inherent problems that constrain capacity and worsen controller workloads. An all electronic system is presently being designed to replace FDEP. It is the Terminal Information Processing System (TIPS). TIPS will accept, store, process, distribute and display flight and other nonradar data for the terminal ATC facilities. Radar controllers will be supplied this information on their existing ARTS III Plan View Displays (PVD), while tower and radar-support positions will be provided with new tabular displays. Exchange of data via the displays will be possible between controllers, between facilities, and with other information sources. (Each TIPS facility will be interfaced with NAS.) The initial design of TIPS has been completed and is now being developed by Lockheed Electronics Co./ Magnavox. Initial testing is scheduled for late 1980, with actual implementation planned for the mid 1980's.

TIPS will increase the availability of flight data to tower and TRACON controllers. At present, only IFR flight data is available from FDEP, and is often delayed due to low data communication speed. TIPS will enable IFR and VFR flight data to be displayed as soon as it is entered into the computer base.

TIPS will facilitate intercontroller communication and reduce controller workload. Today, flight strips must be distributed to the controllers. With TIPS, information will be transferred by a single computer entry action.

3.1.2 Display Description

A TIPS display/data entry unit will be provided to the following positions in the tower: GC, LC, CD and FD. In the TRACON, the arrival data and departure data positions will also have TIPS units. Each unit contains:

- A CRT tabular display
- A 'Quick Action" data entry unit
- A 'Quick Action' hand control unit
- A keyboard

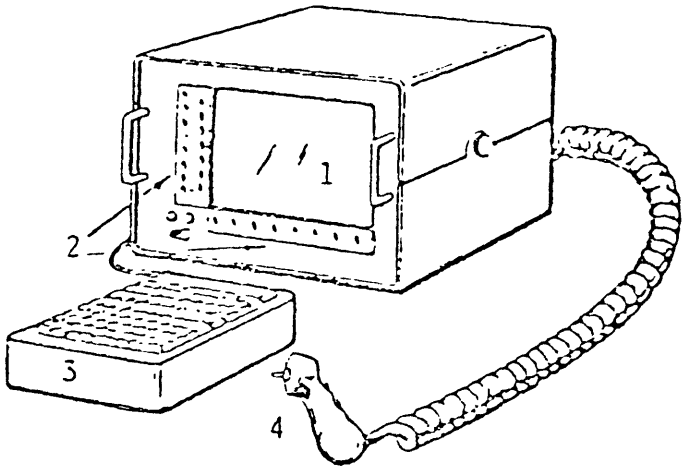
Figure 1 gives an illustration of the display/data entry unit. It will be 14 inches in height and depth and 18 inches in width. The display will be approximately 9 by 12 inches. (68 characters across). The general display format is shown in Figure 2.

The lower third of the display will be the same for all controller positions. A brief description of the areas contained in it follows:

Readout Area - consists of 4 lines and will be used to display flight plans and requested weather and status information. Paging capability is provided for readouts of more than 4 lines.

Preview Area - Consists of 2 lines and will be used to review controller-entered data (via the keyboard) prior to computer processing.

Computer Response Area - consists of 2 lines and will be used primarily to indicate the acceptance (or non-acceptance) of manually entered data. It will also be used to note significant flight data transactions and system problems.



(1) TIPS DISPLAY

(2) TIPS QUICK ACTION DATA ENTRY UNIT

(3) TIPS KEYBOARD

(4) TIPS QUICK ACTION HAND CONTROL

FIGURE 1: TIPS DISPLAY/DATA ENTRY UNIT

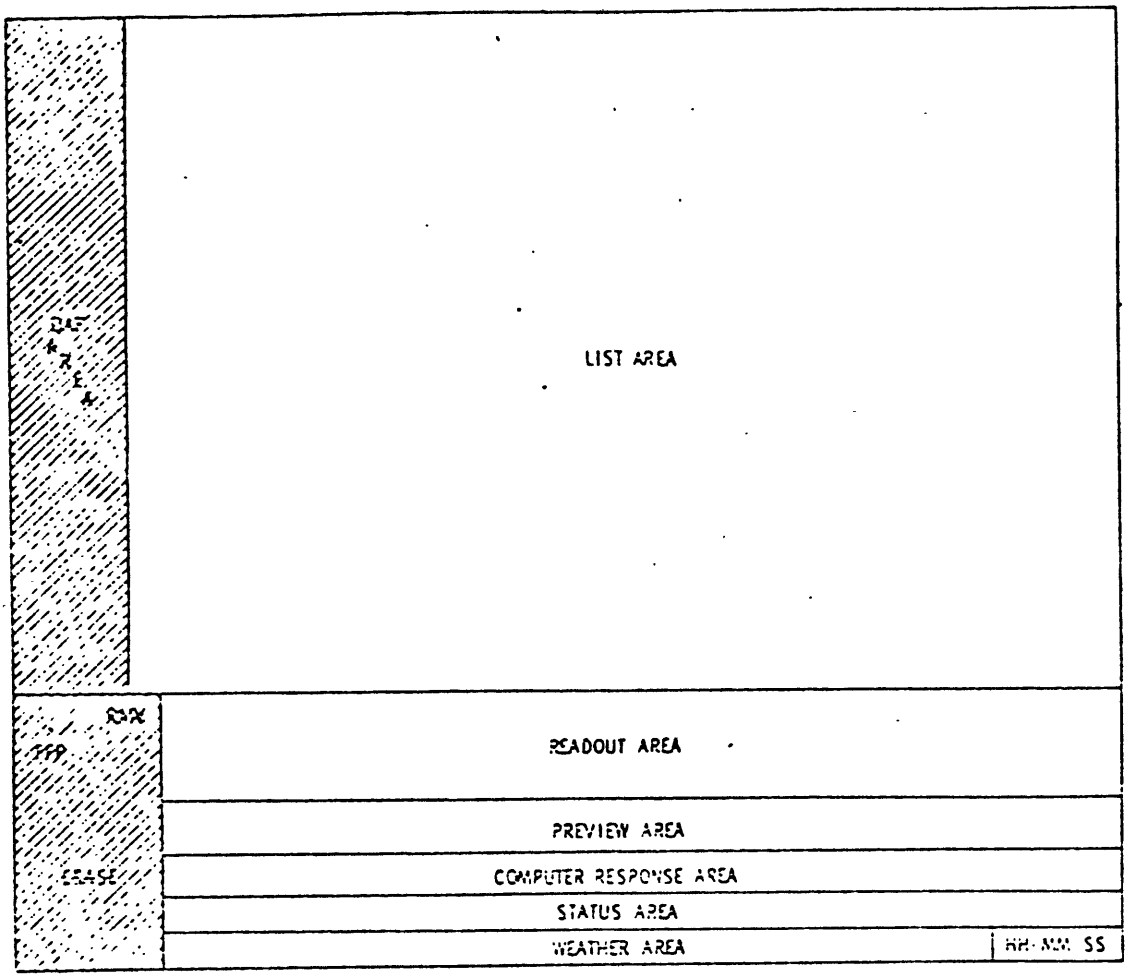


FIGURE 2: TIPS DISPLAY PRESENTATION FORMAT

Status Area - consists of 1 line and will be used to display general system information, such as active runways and NOTAMS. The information will be automatically updated as revised data enters the system.

Weather Area - consists of 1 line and will be used to display local weather information. It will be updated automatically and by controller inputs.

Time - hours, minutes and seconds will be displayed in the right corner of the weather area.

The upper two thirds of the display will be used to present departure and/or arrival flight lists. The specific format for the tower positions is described in Section 3.2. In Figure 2, the shaded areas on the left of the screen depict where the available quick action functions will be listed.

Procedures most often required of controllers are incorporated into the quick action functions. The Quick Action Data Entry unit provides an easy method for acting on specific information being displayed. The unit consists of 2 panels of pressure sensitive buttons located on the left side and along the bottom of the display. An example

operation of the Quick Action Data Entry unit is presented in Appendix B.1. Quick action functions available to each tower controller are also discussed in Appendix B.2.2.

The Quick Action Hand Control Unit will be provided to the local and ground controllers. It will permit them to range up to 10 feet away from the TIPS display and still be able to operate the quick action functions. Selected information or functions on the display will be identified by moving a cursor which consists of the intersection of a vertical and horizontal line. Routine handoffs will be accomplished by pushing a single button. An illustration of the Hand Control Unit is shown in Figure 3.

The TIPS keyboard is adapted from the ARTS III keyboard. It will allow a full range of data entry and editing actions. Necessary TIPS functions and capabilities will also be provided. The keyboard is shown in Figure 4.

3.2 TIPS Description by Tower Position

3.2.1 Ground Control

GC will be presented with arrival and departure lists containing flight data for the aircraft he is responsible for. Each arrival entry will contain:

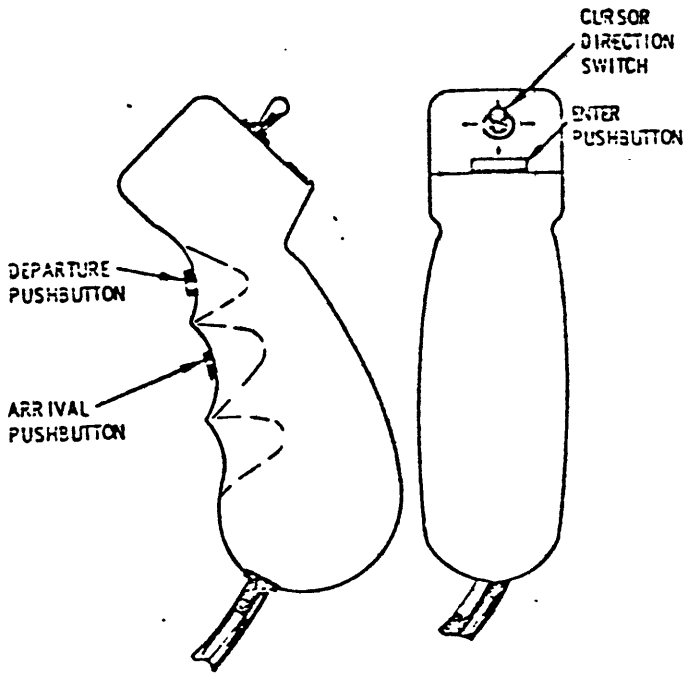


FIGURE 3: TIPS QUICK ACTION HAND CONTROL

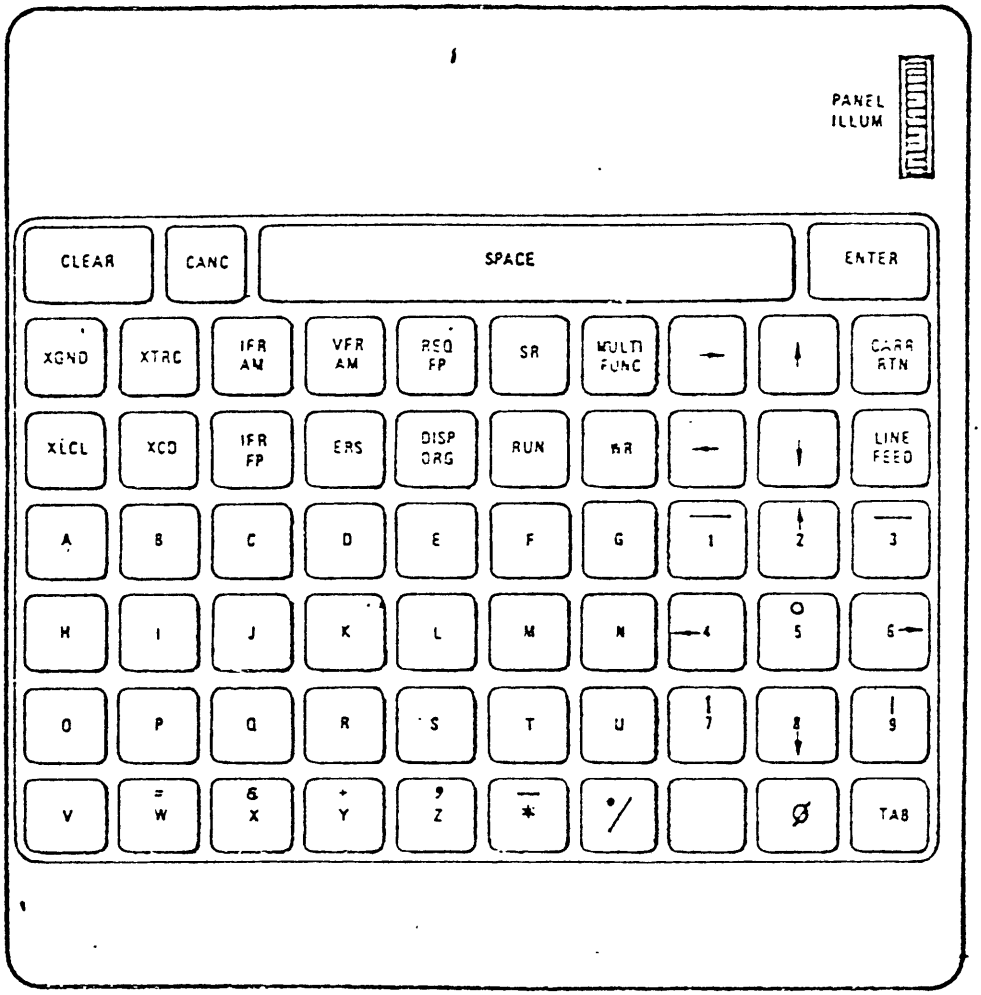


FIGURE 4: TIPS KEYBOARD

-Aircraft Identification (ACID): 2-7 characters

-Aircraft type: 2-5 characters

-Assigned Runway: 4 characters

Different list arrangements will be available. Included will be alphanumeric ordering, chronological (by ETA) ordering, and sorting into sublists by assigned runway.

The departure list format will be:

- ACID: 2-7 characters
- Flight status: "I" for IFR, "V" for VFR
- Aircraft type: 2-5 characters
- Assigned runway: 4 characters
- Coordination fix: 3 characters
  (or heading for VFR flights)

Possible list organization will be by alphanumeric or chronological order, sorting by assigned runway, and by order of handoff from Clearance Delivery.

An illustrative display presentation for GC is shown in Figure 5. The departures are sorted into Active (pilot has contacted GC) and Pending (no contact yet) Lists. Active is in chronological order and Pending is in alpha-numeric order. GC can resequence a pending flight into the Active list when contact is made. The display of "MORE" at the the bottom of the departure list means that there

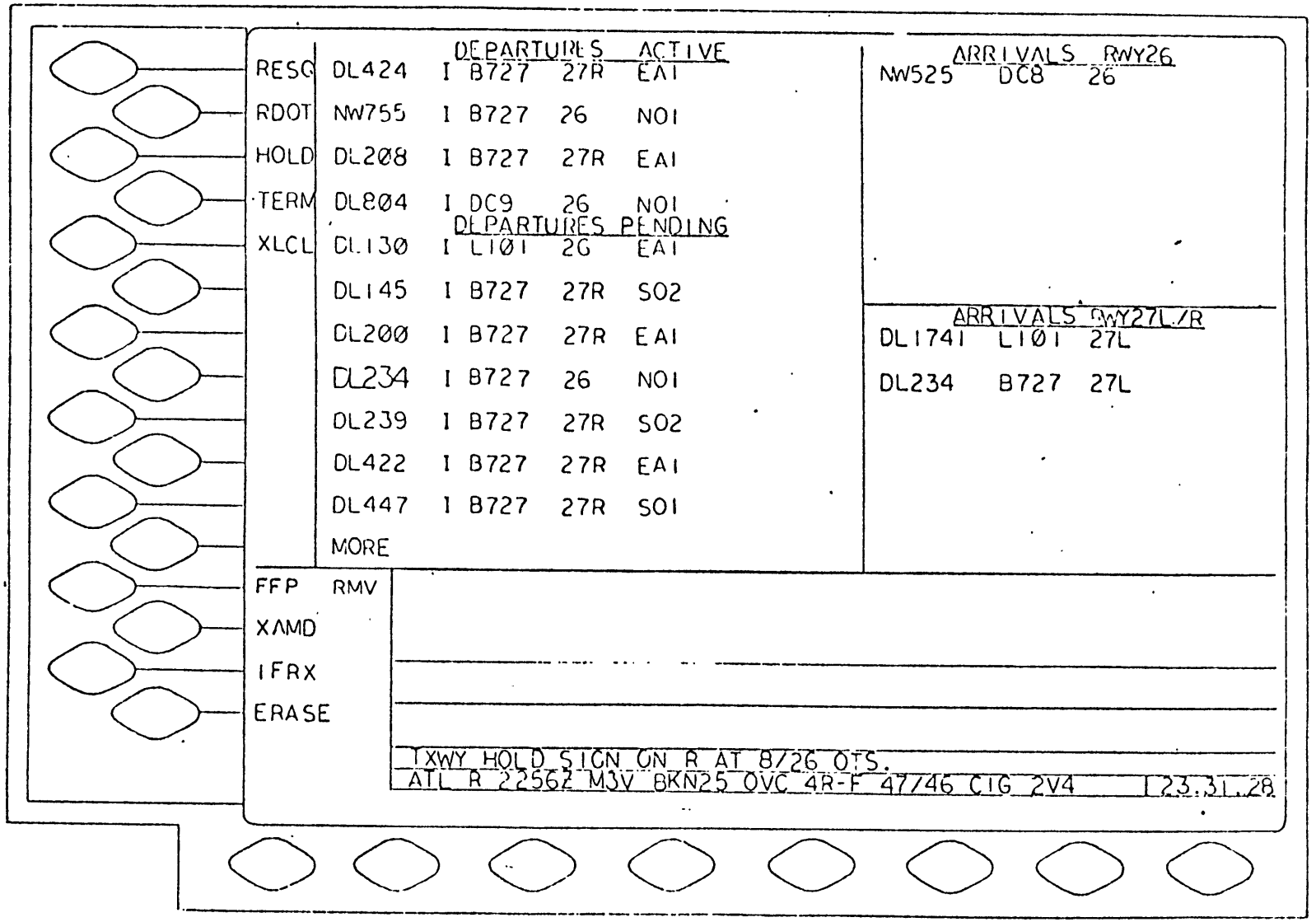


FIGURE 5: EXAMPLE TIPS DISPLAY PRESENTATION FOR GROUND CONTROL (GC-2)

are more pending entries and they have to be paged. The controller can display the rest of the information by pressing the quick action button adjacent to "MORE". This is known as paging and will be required for any controller display where the number of entries exceeds the screen capacity. The arrivals are grouped by assigned runway and appear at the bottom of the appropriate list as they are handed off to GC. In this example, the ACID DL234 has been selected (it is enlarged) so the quick action functions that require ACID pre-selected are displayed. A description of the quick action functions available to GC is contained later in Appendix B.2.2.2).

In Figure 5, the readout, preview, and computer response areas are blank. The status area provides the information that the hold sign for Taxiway R at Runway 8/26 is inoperative. The weather area states:

ATL R 2256Z:	weather report issue for Atlanta at 2256 Zulu time.
M3V:	barometric pressure 3 millibars and variable
BNK25:	broken clouds at 25,000 feet
OVC 4R-F	overcast; 4 mile visibility in rain and fog
47/46	temperature and dewpoint
C16 2V4	ceiling variable between 200 and 400 feet

The current Z-time is given in the lower right hand corner.

3.2.2 Local Control

The arrival and departure lists presented to LC will contain all the data included in the GC format, plus additional information.

To the departure list will be added:

- Assigned beacon code: 4 characters
- Requested altitude: 3 characters

LC Departure list organization will have available the same arrangements as GC, except all departures will be active.

The arrival list will also include:

- Assigned beacon code: 4 characters
- Approach type: 1 character (e.g. "I" for ILS)

The same arrival list sorting options will be available to LC as to GC.

Figure 6 shows an example LC display. Departures are listed in their take-off sequence order. Flight data for each handoff from GC is added to the bottom of the departure list. The flight data entry fields, from left to

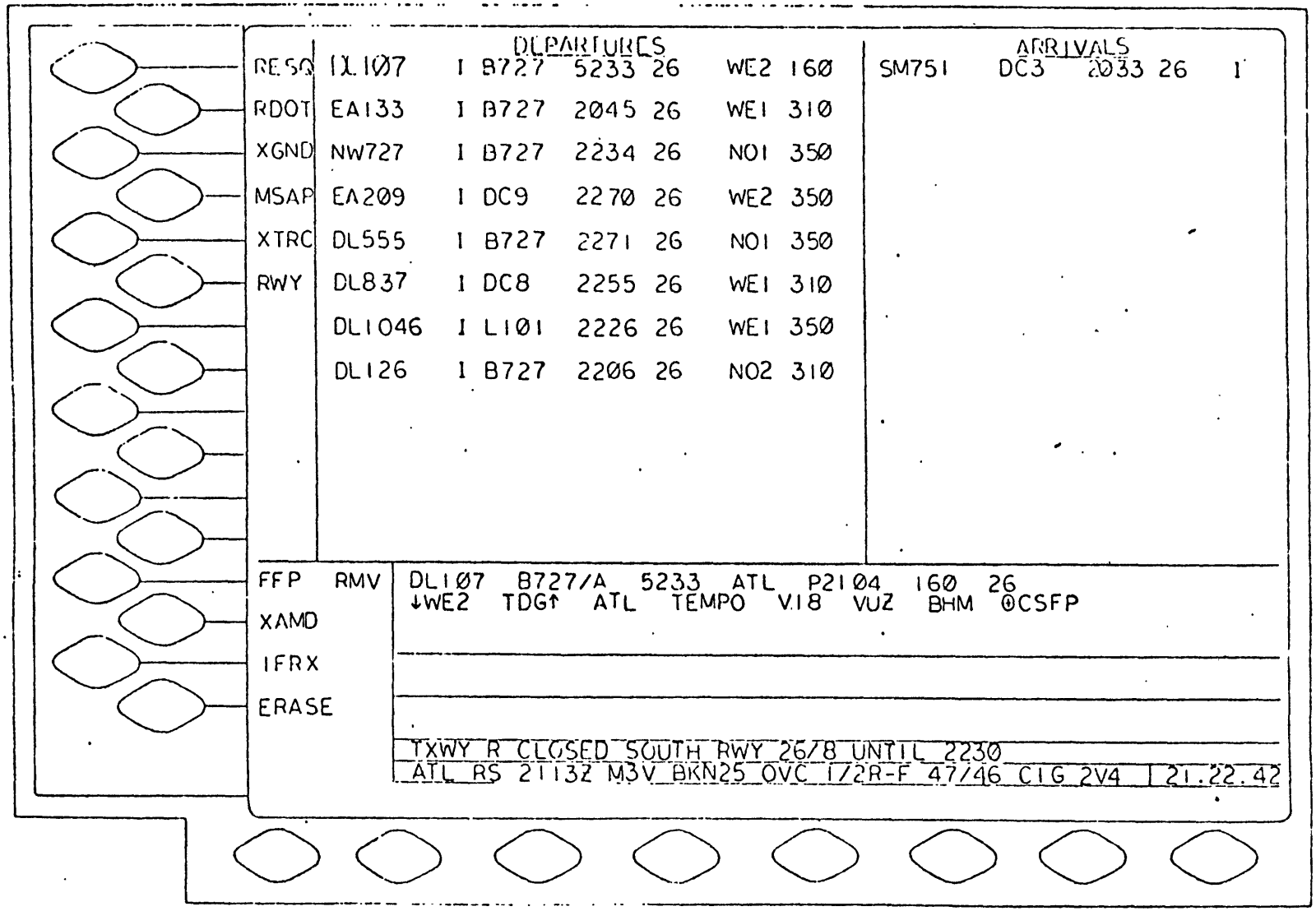


FIGURE 6: EXAMPLE TIPS DISPLAY PRESENTATION FOR LOCAL CONTROL (LC-3)

right are: ACID, flight status, aircraft type, beacon code, assigned runway. coordination fix, and requested altitude.

For arrivals, only one entry is shown. There never will be many flights listed since only a limited number are ever handled by LC at one time. The arrival list entry fields, from right to left are: ACID, aircraft type, beacon code, assigned runway, and approach type.

In this example, the quick action functions are displayed because DL107 has been selected for further action. The flight plan will remain in the readout area until action is taken to transfer the flight, clear the area, or select another flight.

The basic format for a Flight Plan Readout is:

line 1: ACID ∅ Aircraft Data ∅ Beacon Code ∅ Speed ∅ Coordination Fix ∅ Coordination Time ∅ Altitude ∅ Assigned Runway

line 2 and following: + Applicable Preferred Departure Route or Preferred Arrival/ Departure Route + ∅ Route

line N and following: # Remarks

Clearance Delivery

TIPS will present CD with an ACID list containing all the aircraft scheduled to depart within a pre-determined time period from the present. The ACID list will be organized in alphanumeric or chronological (by PDT) order.

There will be an area on the display reserved for flights transferred from GC or LC for amendment. The entries will be of the form:

'ACID' from GC# (# specifies which GC
or or LC, if there are
'ACID' from LC# more than one)

Figure 7 shows the TIPS display for CD. The ACID list is organized in alphanumeric order (the method used by CD with flight strips today). Only 4 of the 5 possible columns for Pending Departures is being used. The Amendment Transfer List is blank.

The flight plan for DL407 is being displayed in the readout area. The quick action functions that involve flight plans in the Readout Area are therefore displayed. Quick action functions which require pre-selection of an ACID are thus not shown, since they disappear after an ACID

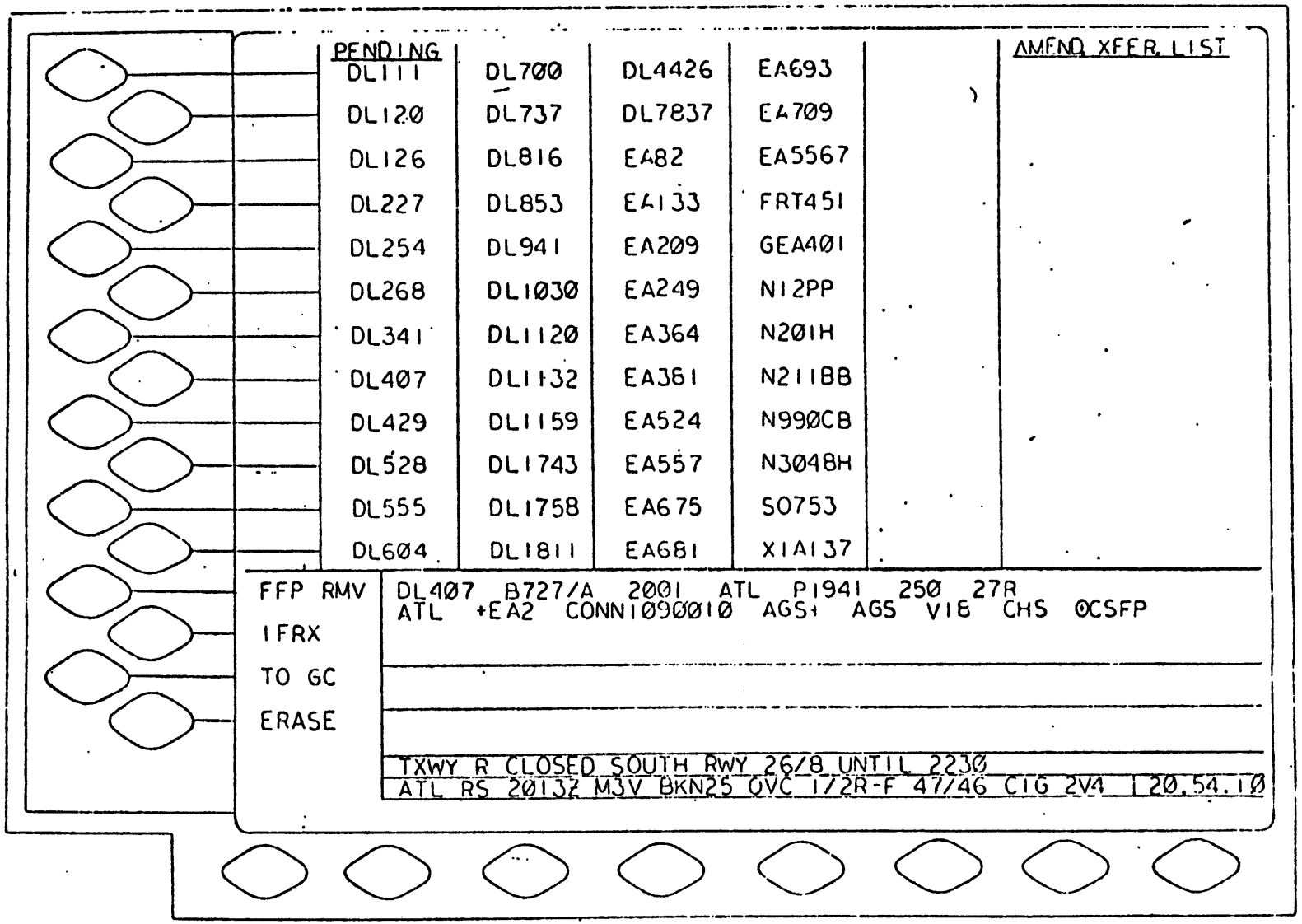


FIGURE 7: EXAMPLE TIPS DISPLAY PRESENTATION FOR CLEARANCE DELIVERY (CD)

is read out. A description of CD functions is given in Appendix B.2.2.4.

Flight Data

FD will be given the same display format and ACID list as CD. The Amendment Transfer List will contain only entries sent to FD. All the quick action functions for the FD position will be the same as for CD, except 'RDOT'. When implemented, it will always result in the full flight plan being displayed in the Readout Area (See Appendix B.2.2.5).

4.0 Other Systems Under Development

4.1 Discrete Address Beacon System (DABS)

An important capability of an automated ATC system will be discrete (directed to a particular aircraft) data link of messages and information. Increased speed and integrity of transmitted messages, along with direct link to weather and advisory sources, will result in imporved safety of flight operations and a reduction in pilot and controller workload due to two-way voice communication.

The program presently underway at the FAA, with support from MIT's Lincoln Laboratory is the Discrete Address Beacon System (DABS). The two-way digital data link capability inherent in the signal structure of DABS will have applications in the following areas: ATC automation, weather delivery, and terminal information. DABS is being designed with maximum flexibility to allow for interface with a wide range of systems and avionics. This will permit the introduction of enhanced services in an evolutionary manner; DABS is applicable to services that will be desirable in an advanced automated ATC system. Initial implementation of DABS is scheduled for the early 1980's. Some of the functional uses of DABS now being considered are presented below. The interface of DABS in an advanced system, along with controller interaction is discussed in Section III.

4.1.1 Altitude Assignment Confirmation

Changes in altitude are tranmitted to the pilot by voice communication. Since garbling or misunderstanding can occur, pilots are required to confirm altitude assignments over the voice channel. The potential errors inherent in this method can be eliminated by the use of DABS data link to provide assignment and confirmation to pilot and controller.

4.1.2 Takeoff Clearance Confirmation

Takeoff clearance is presnetly transmitted to the pilot over a voice channel. Misunderstanding of messages can occur by this method. A non-verbal controller activated "traffic light" type system has been developed by the FAA. It is known as VCOVTC (for visual confirmation of takeoff clearance). A supplement to this could be clearance confirmation by DABS data link, which would also allow acknowledgement of message receipt by the pilot.

4.1.3 Minimum Safe Altitude Warning (MSAW)

All ARTS III terminals presently have the capability to provide a warning to the controller when an aircraft is descending below a preprogrammed minimum safe altitude.

The controller must relay this message to the pilot. The time lag between detection and warning transmission could be reduced by using data link to automatically send a MSAW directly to the aircraft.

4.1.4 Automatic Traffic Advisor and Resolution Service (ATARS)

ATARS is a ground based system which will provide collision avoidance information to aircraft equipped with a DABS transponder, encoding altimeter, and a display. The ARARS computer will use surveillance data from DABS to formulate advisories. Messages will then be sent to the aircraft. There will be different types of advisories depending on the level of danger.

- When there is a potential threat of aircraft becoming proximate, the pilots will be alerted and informatoin will be sent to aid them in gaining visual acquisition of each other.

- When the aircraft pose a potential collision threat, additional information will be displayed including advisories to avoid maneuvers which would aggravate the situation.

- If the miss distance is projected to be less than the established limit, both aircraft will receive resolution advisories at a predetermined time before closest approach.

The responsible air traffic controller will be sent an alert message whenever a threat advisory is issued to an aircraft in his sector.

4.2 Enhanced Terminal Information Service (ETIS)

4.2.1 Background: ATIS

A pilot needs certain local information such as local weather, altimeter setting, RVR, etc. prior to landing at or departing from an airport. At major airports, the terminal information is provided by controllers and the Automated Terminal Information Service (ATIS). ATIS is a recorded broadcast of relevent data and advisories transmitted over a VHF communication channel, which the pilot tunes in for reception. It is revised about once every hour. On initial contact the pilot informs the controller of the code of the latest ATIS broadcast he has heard. The controller provides an update of necessary information and relays advisories on instructions not contained in ATIS. An ATIS broadcast contains the following data:

- airport identification
- sky condition below 10,000 feet
- visibility if less than 7 miles
- obstructions to vision
- wind direction
- wind speed
- temperature and dewpoint
- altimeter setting
- instrument approach is use
- landing runway(s)

- takeoff runway(s)
- NOTAM's and Airmen's Advisories
- "Check Density Altitude" message if temperature is 85°F or more and tower altitude 2000 feet or more
- other pertinent information
- phonetic alphabet code of the message, and instructions for the pilot to acknowledge receipt by informing the controller on initial contact

ATIS siginficantly reduces controller workload and the loading of communication channels, but it has limitations. Since a controller records the broadcast, there is the potential for human error. A pilot cannot choose or monitor a particular item; he must listen to an entire broadcast. A printed copy of the message is not available, so the pilot must write it down or trust his memory. Also, due to the line of sight characteristics of VHF transmission, ATIS is available only locally and on limited areas of the airport surface.

4.2.2 ETIS Features

By use of the DABS data link, most of the above problems can be circumvented, while adding new services and features. The concept presently underdevelopment to provide this is ETIS. Some of its features will be:

- Direct relay of most information using automated sensors, independent of a human operator.

- Ability to receive ETIS whenever DABS coverage is present

- Ability of the pilot to request only the information he needs

- Automatic transmission of alerts or significant changes in information

- Capability for making hand copy

- Elimination of most of the inherent ATIS errors

- Provision of digitized voice messages to non-DABS equipped aircraft.

4.2.3 Message Types

The following information will be included in ETIS:

- Runway(s) in use
- Approach(es) in use
- Sky condition
- Prevailing visibility
- Precipitation type
- RVR (Runway Visual Range)
- Center Field Wind
- Runway Wind or Sector Wind

- Center Field/Runway Wind Vector Difference contained in wind shear alert (speed, direction)
- Temperature
- Dewpoint
- Altimeter Setting
- Rate of Barometric Pressure Rise (Alert (--- inches Hg in --- minutes)
- Rate of temperature drop (--- degrees F in --- min.) (Alert)
- Thunder storm location, direction, speed (if available) (Alert)
- Density altitude (Alert)
- Airport advisories (such as ice patches, runway braking action reports, closed runways or taxiways, noise abatement procedures, construction equipment, out of service nav-aids, special instructions for VFR arrivals, etc.).
- Time of day of ETIS data (if required)
- (Wake vortex detection warnings?)

ETIS messages, with appropriate contents will be dispatched based on: phase of flight or aircraft location, a change on occurrence in ETIS data, and pilot request. The initial arrival ETIS message will be sent automatically to aircraft entering the terminal area. All the data from the above list can be included in the message (alerts if applicable, RVR and density altitude if necessary). A Final Approach message will be dispatched when the aircraft is near the outer marker or final approach fix (this is where

handoff to final control takes place). It will contain center field wind, runway wind and RVR or prevailing visibility. Departure ETIS will be transmitted upon pilot request prior to departure. It will contain the same information as an arrival ETIS message except for the exclusion of appraoch in use and RVR. Alerts will be sent automatically, as soon as conditions warrant, to aircraft which have received the initial or departure ETIS message. The pilot will also be able to request any specific items(s).

Non-DABS equipped aircraft will receive ETIS messages via a Digital Voice System (DVS) VHF broadcast. The time of message formulation will be included to indicate validity of the data. Since the pilot must 'tune in' to receive the message, alerts and updates will not be able to be automatically dispatched. A controller will have to relay this information.

ETIS will be compatible with other ATC system. Interface with TIPS is desirable since it will provide the controllers with constantly updated information, in addition to a means to input non-sensor derived data into ETIS (e.g., runway in use). An interfaced ETIS/TIPS will also be able to furnish some of the information that an advanced sequencing and scheduling algorithm (ATM/C) will need.

These interfaces and coordination are discussed later in Section III (8.0).

4.3 Airport Surface Traffic Control (ASTC)

All aircraft and ground vehicles are directed on the ramp and taxiways by the ground controller(s) and on the runway(s) by the local controller(s). Communication is by voice radio. During times of good visibility, the controllers base their decisions on visually surveyed information. When viewing is diminished or obstructed, the controller must rely on pilot position reports, in conjunction with the display of surface radar data (if available). Communication and resulting controller workload increase greatly, to the extent that GC, at times, becomes the pacing factor in the execution of flight operations.

Airport Surface Detection Equipment (ASDE) is currently in operation at twelve major airports. ASDE is a ground surveillance radar system that provides a traffic display to the ground controller. But a high level of pilot-controller coordination is required since ASDE doesn't identify its targets as does ARTS.

A new system known as ASDE-3 will have improved resolution characteristics, but still won't label targets. Imple-

mentation is planned for 30 airports over the next few years.

There are several aspects of surface traffic control where improvements can be made; a number of possible solutions are presently being studied. Some form of ASTC will be needed in the advanced system: Scheduling shouldn't be restricted by ground delays. The particular system implemented is not critical, so long as departing aircraft arrive at the threshold on schedule and arriving aircraft aren't delayed by ground control.

A system has been conceived that will use inductive loops buried in the taxiways to detect aircraft. A computer will determine routes. Stop commands will be issued via rows of red in-pavement lights. Directional instructions will be relayed by green centerline lights.

More desirable is to provide the identification and location of each aircraft. The Tower Automated Ground Surveillance System (TAGS), presently under study, will utilize transponder responses to identify and provide labels to targets displayed by ASDE-3. Algorithms can be developed which will provide conflict alerts and routing commands to the controllers. With the introduction of DABS, instructions will be able to be sent to the pilot via his cockpit display.

The ASTC interface and resulting controller requirements for the advanced system is discussed in Section III (6.0).

4.4 Air Traffic Management and Control Automation (ATM/C)

4.4.1 General Description

ATM/C will be an automatic, tactical decision making system to reduce delays for both landing and take-off operations at major airports (multiple runway operations included). It will use radar tracking and other data to generate flight plans and optimal runway schedules, and present this information to the controllers on their existing displays.

The ATM/C system can be modelled as a feedback control system, all the elements of which are contained in:

The Aircraft Control (Navigation) System

Air-to-Air Link System

Ground Control System

Ground-to-Air Data Link System

Air-to-Ground Data Acquisition System

Grond-to-Ground Data Link System

The basic state requirements consist of position, velocity and acceleration $(P, \dot{P}, \ddot{P})$ of each aircraft target.

4.4.2 Ground Control System

The controllers will be primarily concerned with the Ground Control System: the Decision Generator and the Traffic Monitor. Figure 8 is a block diagram of the Ground Control System, including inputs and outputs. The Decision Generator will be responsible for the flow of traffic. The input will be the state of each controlled aircraft (P^S, $\dot{P}^S$, $\ddot{P}^S$ - time average values). The output will consist of a flight plan, F_i, for each aircraft. The flight plan, concisely stated, is a set of time-points defining a curve in 4-dimensional space. The Traffic Monitor will ensure adherence to Ground Control decisions. It will also be responsible for enforcement of ATC safety rules and for generating a hazard alert when violation is imminent. 'Hazard' describes the relation between the surveillance positions of aircrat or of aircrft and unsafe or restricted airspace. 'Conflict' refers to the relation between flight plans. By definition, conflict will be checked by the Decision Generator.

The ground control decision process can be further divided into two major functions: Runway Scheduling and

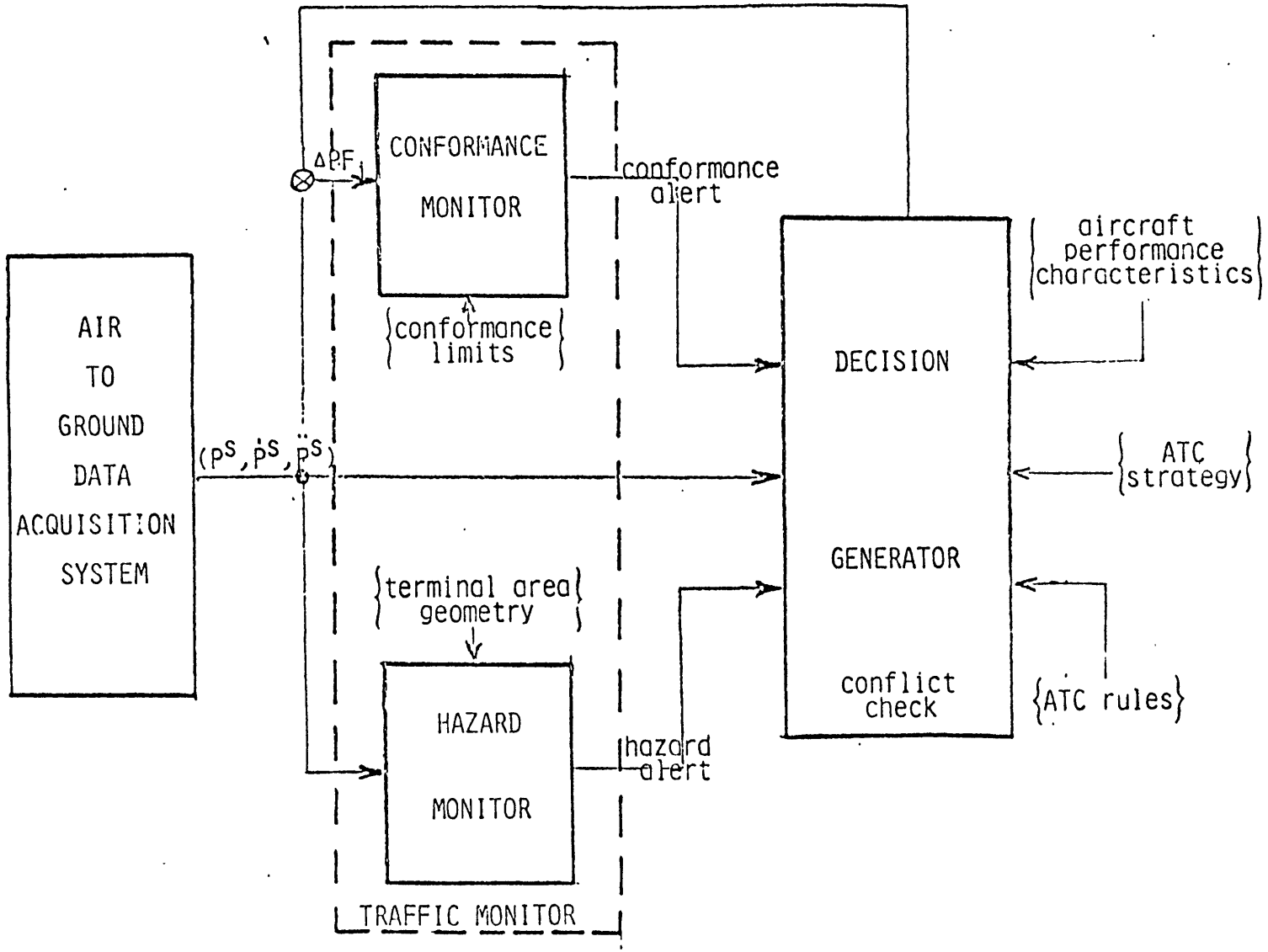


Figure 8 : The Ground Control System

and Traffic Flight Plan Generating.

Runway Scheduler: determines the best (according to some objective function) schedule of runway operations for all aircraft in the ATM/C System (landings and take-offs). The inputs are:

- The current ground control decision
- The nominal sequence of runway operations (the earliest preferred time for threshold arrival of each aircraft)
- The minimum required time separations at the runway threshold
- The maximum number of position shifts allowed

outputs:

- The runway schedule.
- The scheduler will be capable of responding to constraints/overides imposed by the supervising air traffic controller.

Traffic Flight Plan Genrator: Updates the aircraft flight plans subsequent to changes in the runway schedule. The inputs:

- The current routing decision, $F_1, F_2, \ldots F_n$
- The new runway schedule
- Minimum required airborne separations
- Current aircraft positions, $P_1^s, P_2^s, \ldots P_n^s$
- The terminal area network geometry
- The aircraft performance characteristics

outputs:

- The new routing decision, $F_1^*, F_2^* \ldots, F_n^*$

4.4.3 Interfaces

Controller interaction will be with the command processor. The command processor will use flight plan data to generate a set of commands which will navigate the aircraft along its assigned flight path. The controller will remain as the prime link between the ground system and the aircraft (though a scenario of direct data-linked commands is envisionable). The set of allowable controller commands will be of the "radar vectoring" type (specified heading, velocity, altitude, etc.). The controller will be able to effect the decision process in the following ways:

- Overide the computer generated schedule

- Impose additional constraints to the scheduling process (e.g., immediate landing due to an aircraft emergency)
- Request for system reconfiguration (e.g., change the active runways, change the ARC strategy, etc.)
- Validate commands for transmission to various aircraft
- Edit computer generated commands and initiate their their transmission process

ATM/C will aso have to interface with other systems. It will need inforamtion regarding status and conditions (i.e., runways in use, RVR, winds, etc.). ATM/C will interact with the surface traffic control system to get aircraft to their assigned runways (on time). ATM/C interface in the advanced system is discussed in Section III.

III. AN ADVANCED ATC SYSTEM: REQUIREMENTS AND SUGGESTED MODIFICATIONS.

An advanced ATC system, by definition, will provide new or enhanced capabilities to the controller. Care must be taken for the augmented services and information to be made available in a readily accessible and non-confusing manner. Loss of previous system capabilities must be prevented.

The systems discussed in the previous chapters will be the major components of the advanced system. Contained in the next 4 chapters are some proposed modifications and adaptations of these present system concepts to allow for their interface with the controllers and with each other in the advanced system. The objective here is to suggest matters that should be considered as development proceeds on these systems.

The controller responsibilities will remain basically the same as in today's system - the prime concern being safety. He will be provided with information from and assisted in decision making by computerized systems but final accountability remains with the controller. Because of the importance of controller/computer interaction, Section III is largely concerned with display/data entry units. Some of the proposed display/data

entry unit functions and requirements are presented. Since TIPS will be a "hub" for the other systems, emphasis is placed on it, though not exclusively.

5.0 General

The following apply to TIPS and radar displays in the tower and TRACON:

5.1 Controller Inputs

The controller will interact with the various systems via his display/data entry unit. Certain controllers will enter airport status or flight plan data. Controllers will initiate control functions, call-up needed information from the data base, and relay messages to the pilot. Required controller actions should be as simple as possible.

5.2 Command Display

Computer generated decisions and commands will need to be presented to the controller for validation before any action is taken. The associated aircraft and the time at which to initiate the instructions must be included with the command message. Two possible methods:

- For displays with Flight Data Blocks (e.g. ARTS PVD), include the message in the block (will require an extra line or two).

- Have a dedicated area, with a series of commands

(ACID and time, too) that the controller will issue in the next period of time. This is applicable to TIPS, where there won't be enough space in the aircraft's flight data fields.

The ATM/C system will issue vectoring commands and the ASTC system will provide ground routing instructions. Some example message formats are given in Appendix C.

Message will be data-linked to DABS equipped aircraft and provided by voice radio to others. An indication that the message is received and acknowledged by the pilot will be provided (see Section 5.3). Controllers will have quick action means to automatically relay directions to DABS aircraft (see Section 5.7).

5.3. Pilot Response

A means to indicate data linked cockpit responses to ground initiated requests will be required. There are several possible methods:

1.) Have a dedicated area located on the display to present the pilot responses. (For TIPS, this could be a portion of the Computer Response Area.) The replies may be of the form:

displayed message	meaning
WILCO	Acknowledged, will comply
UNABLE	Unable to execute command
QUEST?	question regarding previous request, provide more information.
NO/REP	no reply (displayed after a predetermind time period)

note: it may be desirable to include the ACID of the responding aircraft (eg. AA123: WILCO)

2.) Since the message to be data linked to the pilot will be presented on the controller's display, have the response appear next to the message. A single letter or symbol may be all that will be necessary (i.e. W,U,?,NR).

3.) In some instances it may be desirable to have redundancy or a longer lasting reminder of the request and response. An example is to denote clearance confirmation in the aircraft's flight data field on the TIPS display (see 6.1.3 and 6.1.4).

5.4 Alerts

ARTS, ATM/C, ASTC and ETIS will automatically relay alerts and notifications of critical situations to the appropriate controller (s), and in many cases, to the pilot as well. Provision must be made to distinguish the type and urgency of each alert. An alert will remain in effect until it is acknowledged and the situation is rectified. Some methods for presenting alert messages follow:

1.) Have a dedicated alert area where the type of alert will appear, and if necessary, the aircraft to which it applies. (For TIPS, a section of the Preview Area could be used).

2.) For aircraft related alerts, have the message appear in the Flight Data Block or field, overwriting the information already there.

3.) Couple the above methods with another indicator. Examples are: audible alerts, warning lights, flashing the displayed alert. Audible alerts will especially be needed in the tower, where ground and local controllers range away from their displays.

5.5 Flagging

Certain aircraft status or state information can be denoted by marks or symbols instead of printed words. For example, in today's system the controller puts a check mark on the flight strip when the assigned altitude is transmitted. The displays in an advanced system should provide automatic and/or controller initiated means of underlining, blocking in, or adding symbols to pertinent data.

5.6 Avionics Capability

The computer systems and controllers alike will have to be informed of the communication and navigation capabilities of each aircraft. All aircraft flying within a TCA are required to have a transponder, but there will be a mix of ATCRBS and DABS. Though the DABS system will accept data communication from ATCRBS transponders, data-linked messages will not be possible since ATCRBS doesn't have display capabilities. There will also be various DABS cockpit display capabilities among the aircraft mix.

These differences affect how information will be communicated. A Digitized Voice System (DVS) may be included in the DABS system. This will provide messages to non-DABS equipped aircraft over a radio frequency.

All forms of communication will be supplemented by controller voice transmission via radio, when required.

The DABS ground system will be able to automatically determine avionics capability from the transponder response. The controller must have this information displayed to him. Each controller display in the advanced system will be able to present beacon codes. The beacon code can be used to denote avionics by:

- including a single-character symbol with each code to indicate type of avionics.

- allocating beacon code numbers according to the avionics capability.

Control message format will depend on navigation capability (e.g. issue a series of way points for RNAV equipped aircraft). This information will be determined and provided to the computer systems and controllers as described above.

Any avionics malfunction or failure must be reported to the controllers and computer so that appropriate action can be taken. Controllers will be alerted as described in Section 5.4.

5.7 Command Validation and Relay

ATM/C and ASTC will present computer generated control decisions to the controller for validation and relay to the appropriate aircraft. The controller should be provided with a simple input method to acknowledge a displayed command or to indicate that he will override the computer decision. In all cases, there will be a time period between when the command is displayed and when it must be issued. For some commands, the controller may pre-validate them (the instructions will then be automatically dispatched to the aircraft by the computer at the appropriate time). Input functions to be available on initial display of a command instruction:

- 'ACKNOWLEDGE'- Validates the computer decision; indicates to the computer that the action will be taken

-'PREVAL' - Validates the command and also tells the computer to automatically dispatch the message at the appropriate time.

-'OVERRIDE' - Informs the computer that the controller issued a different

command than the one displayed.

- 'OVERRIDE' can be used after 'ACKNOWLEDGE' or 'PREVAL' if the controller should change his mind.

For dispatching messages, the controller should be provided with a quick action input 'RELAY'. 'RELAY' will transmit a designated (displayed in a special area, or flagged) command to the appropriate aircraft. For non-DABS equipped aircraft the controller will use the voice channel, so 'RELAY" will be used to inform the computer that the command has been issued.

Both systems will provide alerts to the controller and the pilot when the aircraft deviates from its presented path or when there is danger of a collision. In the case of a collision alert, where expendiency is required, rectifying commands will be linked directly to the cockpit without controller validation. This will avoid the time lag inherent in controller relay. Hopefully collision alerts will be rare, since the paths of all aircraft will be predetermined and flight progress will be monitored by ATM/C.

5.8 Reconfiguration of Active Runways

ASTC will have to interact with ATM/C so that departing aircraft are delivered to the correct runway at the appropriate time. Provision must also be made to route arriving aircraft from the landing runway to its assigned gate (section 6.2.2) To accomplish the above, and for ATM/C to make the appropriate Air routing computations, the status of active runway and taxiways must be included in the computer data base. Active runway changes, along with individual aircraft runway assignments, will be automatically dispatched to ATM/C, ASTC, ETIS and TIPS systems so that necessary coordination action will take place.

For the actual process of reconfiguring active runways, the Team Supervisor (TS) in the tower will be responsible for the final decision. He will be aided by computer derived suggestions based on the following information:

- predetermined noise abatement procedures
- weather (e.g. thunder storm avoidance)
- general wind conditions
- optimal cross wind for wake-vortex avoidance
- changes in RVR, wind shear, etc.
- runway or taxiway status (i.e. ice, construction, etc.)

The computer system will automatically notify the TS (or another controller) when reconfiguration is necessary, or the TS may initiate a change and enter it into the data base, The time for which the reconfiguration will be in effect must be made known. The TS will interact with the system via a TIPS display/data entry unit (the tower Input/Output Terminal).

5.9 TIPS List Display Requirements

The arrival and departure lists on the GC and LC display should be chronologically ordered automatically according to runway. For each aircraft the appropriate coordination time should be displayed:

- for LC Arrival: display ETA (estimated time of arrival)
- for GC Arrival: display ETG (estimated time to gate)
- for GC Departure (Pending):display ETT (estitime to taxiing)
- for GC Departure (Active): display PDT (proposed departure time)
- for LC Departure: display PDT

5.10 ATM/C Information Requirements

The ATM/C system will require access to and input of a wide selection of information to generate schedules

and flight paths. The objective of the advanced system is to provide information automatically when possible (system interfaces) and to make manual entries as simple as possible for the controller. Some specific data needs are mentioned throughout Section III (and also Section 4.4) A complete list of all the necessary information for ATM/C is beyond the scope of this study; a list of some information categories is presented below:

- Airport Status: (active runways)
- Weather;Wind: (i.e. to determine headwinds for airspeed estimation; Wake Vortex Avoidance data to reduce separations, etc.)
- Tracking: (Position, speed, altitude, etc. from radar tracking system)
- Aircraft and Pilot Parameters: (Performance characteristics, navigation equipment, requested final approach speed, etc.)

- Schedule Parameters: (Earliest possible arrival time at runway, desired time of arrival, assigned runway, etc.)
- Controller Information: (aircraft/controller pairings, generated command status: acknowledge, prevalidate overrides, etc.)
- Algorithmic Parameters: (Separation standards, maximum number of position shifts, etc.)

6.0 Traffic Control Functions

6.1 Air Traffic Management and Control

Presented below are some of the coordination requirements for control of air traffic.

6.1.1 Handoffs

First a question needs to be resolved: Will ATM/C indicate when to make a handoff or will it still be controller determined based on standard operating procedures? Whatever the case, handoffs via TIPS will take place as described in Section 3.0 and those via radar displays (including ASTC and BRITE) will be by the ARTS trackball/entry method.

An important development in the advanced ATC System is that some handoffs will cue the action of other functions:

- Handoff from ARTCC to Arrival Radar and from Arrival Radar to Final Control will trigger ETIS dispatch messages (see Section 8.4)

- Frequency change messages will automatically be relayed to the pilot (no need for controller validation - handoff implies it) and displayed to the controller (for the purpose of referencing the pilot response message).

- Notification messages will be sent to each computer system to inform them of which controller has jurisdiction over which aircraft, sc that messages and data will be routed to the correct controller.

For the situations where the controller will have access to more than one display, have acceptance or initiation of a handoff be required from only one display (automatically implied on the other). This pertains to two tower controller positions:

- handoff to Local Control from Final Control via TIPS or BRITE (ARTS).
- handoff to or from Ground Control to Local Control via TIPS or ASTC.

6.1.2 Missed Approach

The present TIPS design has a 'MISSED APPROACH' quick action function at the LC position. At the occurance of a missed approach, use of this quick action will transfer flight data back to the TRACON so the flight can be resequenced for another approach. The flight data is deleted from the LC display at this point.

Controller coordination will be facilitated over

today's system by this design; but in an advanced system further enhancement will be required. Activation of the 'MISSED APPROACH' quick action will inform the ATM/C computer of the situation. The computer will respond by:

- immediately displaying a message to LC for relay to the aircraft.

  ex: EXCT/MA (execute missed approach procedures; take up initial heading of 300 deg.)
  HDG/3ØØ

- computing a new arrival schedule and a new flight path for the aircraft.

- dispatching a message to the appropriate airline to reassign the aircraft's gate.

6.1.3 Landing Clearance

LC will decide when to issue clearance to land. The LC TIPS unit should be modified to have a 'CLEARANCE' quick action function, to be used for either take-offs or landings. When implemented, the quick action function will:

- issue the clearance message to the aircraft

  ex: CLR/LND (cleared to land; indicate a speed of 120 knots)
  SPD/12Ø

- require an acknowledgement from the pilot. This will be signified by a message in the Pilot Response Area and by flagging the aircraft's flight data in the LC TIPS Arrival List. The flagging can be done by underlining the data. This will serve to remind LC that clearance was issued and inform any other controller observing the display of the same.

- trigger a gate assignment request to the appropriate airline. The assignment will be entered into the computer system and be displayed on GC's TIPS display (See. 6.2.2).

- inform the ATM/C computer that clearance has been issued.

6.1.4 Take-off Clearance

LC will decide when to issue take off clearance based on PDT and the runway occupancy status. LC will use the 'CLEARANCE' quick action function on his TIPS unit (See 6.1.3). For take off clearance, the quick action function will:

- issue the clearance message to the pilot.

  ex: CLR/TKOF (cleared for take-off; initial heading 210 degrees)
  HDG/210

- require a response from the cockpit. The flight data in the list will be flagged (underlined).

- trigger the sending of a message to the Departure Radar Controller that clearance is confirmed.

- inform the ATM/C computer that take-off has been initiated

6.1.5 Schedule Information

The ATM/C System will have a tentative schedule for runway use determined about 20 minutes in advance. This data should be made available to LC on a call-up basis. The LC TIPS unit can be provided with a 'SCHEDULE' quick action function which will cause a list of tentative arrivals to be displayed in chronological order and according to runway. The list will contain all the aircraft that have been transferred to approach control - some will have a landing time assigned by ATM/C, some further out will only be tentatively scheduled. The flight data will be in standard LC Arrival List format with ETA included. It may also be desirable to have landings included to show the plan for each runway. (Schedule information will also be available to

the airlines.)

6.2 Surface Traffic Control

The Ground Controller will have a surface traffic display at his disposal, which will be used to present aircraft data (in an ARTS-type mode) and to provide the means to display control messages and relay them to the aircraft. It is also possible that the computer generated commands will be presented and relayed via TIPS. It must also be determined how much GC will rely on visual data. (Will automated commands be required in all situations? Will it be feasible to directly data-link messages without controller intervention and have GC act as a monitor?)

For whatever method of surface control used in the advanced system, the following coordination functions must be considered:

6.2.1 Gate Hold Procedures

Gate Hold Procedures are used to reduce the number of unnecessarily early engine starts. Aircraft delayed on the ramp or in the departure queue with idling engines waste fuel and provide excess noise and pollution. An objective of the advanced system is to provide pilots and controllers with ETT (estimated time for start

of taxiing) so that plans can be made accordingly.

Interface with ATM/C will furnish the ASTC algonthm with the PDT and the assigned runway for each aircraft. This will enable the computer to determine the ETT for each aircraft and keep the departure queue lengths under a prescribed length. The ASTC computer will update planned routes and ETT's when other delays arise.

Clearance Delivery (CD) issues pre-departure clearance on pilot request. This clearance consists of CD providing the pilot with flight plan data (see Section 2.2 or App. A). Issuing of pre-departure clearance will indicate to the computer that the aircraft has officially entered the system. ETT will be provided to CD and the pilot in flight plan data readouts (along with PDT). The aircraft will be handed-off to GC after pre-departure clearance is given. Flight data for each aircraft will be automatically listed in chronological ETT order in the GC TIPS display Pending List (with ETT displayed). Notification messages will be sent to GC and the pilot whenever significant changes in ETT ($\pm$5 min (?)) take place. Flight data will automatically be transferred to the GC Active Departure List (with PDT displayed), once taxiing commences.

6.3.3 Gate Assignment

Knowledge of the assigned gate for each arriving aircraft will be necessary for formulating the taxiing route. At major terminals, gates are assigned by the airlines.

In the advanced system, a notification message will be automatically dispatched (triggered by LC issuing landing clearance) to the appropriate airline. The message will be of the form:

'ACID': CLEARED TO LAND
GATE ASSIGNMENT REQUESTED

The airline should expect the message since it will have a list of scheduled arrivals and their ETA's available (see section 6.1.5) (so a gate assignment may have already been made). The gate assignment reply will be relayed to the ASTC and ATM/C computers. This will allow ASTC to prepare the taxiing route. Gate assignments will be included in the GC Arrival List flight data entries.

7.0 Flight Data Functions

The primary function of TIPS is to handle flight plan data. This was described in Section 3.1. along with the tower controller requirements in Section 3.2. In the advanced system, flight plan data will be provided or validated by the ATM/C computer. There will also be the capability to data-link this information to and from the cockpit.

A tower controller will serve as a relay point for flight data traveling between the aircraft and the ATM/C System. Flight plans will be available for readout to each controller (see section 3.2 and App. B.2). Any changes determined by the ATM/C computer will be sent to the controller along with a notification message. Changes requested by the controller or pilot will have to be entered in the ATM/C computer for validation. The computer will respond with either an acceptance message or another suggested modification (it will be assumed that the present data requiring change is unacceptable to the pilot).

A quick action function ('TO A/C') should be available on the TIPS units for CD and/or FD. This will enable the controller to relay flight plans or flight data changes displayed in the Readout Area directly to the pilot. Acknowledgment will be displayed in the pilot

response area. (It is assumed that other controllers will transfer flight data to CD or FD for amendment as suggested for the current TIPS system design (see App. B.2).)

Flight plan filing will be available via data-link from the cockpit. It must be determined what controller intervention will be required. A possible scenario is to have the pilot link the data or requested changes to CD or FD; but input (via a cockpit keyboard) may be a workload problem. Instead, have an input key available in the cockpit which will cause a 'Transfer for Amendment' message to be sent to the controller's display. The ACID and the words "from A/C" will appear in the amendment list and the flight plan will appear in the Readout Area. (This is how transfers from controllers are to be done in the current TIPS design) The pilot will then relay his change requests over voice channel. The controller will enter the data and receive a response from the computer. The controller will transmit the data back to the piolt via data-link (activation of 'TO A/C').

Note: Air line flight plans will be prefiled with NAS from ground stations before flight. There will be only minor changes or additions at clearance delivery time.

8.0 ETIS Information

Controllers in the tower and TRACON will need access to ETIS information (see section 4.2). TIPS will provide the means to display the ETIS data and alerts. The TIPS display/data entry unit will enable certain controllers to input data for incorporation into ETIS messages. The ETIS system will take cues from certain TIPs functions or information to automatically dispatch messages.

8.1 Display Requirements

The objective is to present all of the ETIS data to the controller in a readable form (each item labelled). This will be done on a call-up basis. A dedicated area for continuous display will not be needed since the controller will use the information only on an occasional basis. Also, pertinent data will be presented in the TIPs Status and Weather Areas and the controller will be automatically notified of significant changes in ETIS information.

Each controller will be able to call-up the ETIS information by activating the 'ETIS'quick action function incorporated into his TIPS display/data entry unit. This function will cause the ETIS data to be displayed in the Readout Area with each item labelled. See Figure 9 for an example presentation. Paging and clearing of

TIPS Readout Area

ETIS BOS 1221	TEMP 46/44	APR ILS 22L/RVR 51
SKY 25S/33S/58B	ALT 3004	APR ILS 27/RVR 49
VSB 1/2 RF	DEP 27	WND 26/04/00
BRK F 22L 707. TWY G CLSD. VFR AC CTC APR 126.8		

Explanation (from left to right):

ETIS for Boston at 1221 Greenwich

Temperature 46°, Dewpoint 44°

ILS 22L approach in use with RVR at 5100 feet

Sky is 2500 feet scattered, 3300 feet scattered, 5800 feet broken

Altimeter setting 30.04 inches Hg.

ILS 27 approach in use with RVR at 4900 feet

Visibility is 1/2 mile in light rain and fog

Departures on Runway 27

Wind from 260 degrees at 4 knots, no gusts

Braking action is fair on Runway 22L by a 707; Taxiway G is closed; VFR aircraft contact approach on 126.8

Figure 9: Typical ETIS Message

the Readout Area will be the same as for other TIPS functions using it.

8.2 Alerts and Notifications

ETIS will automatically dispatch alerts or notifications of significant changes in information directly to aircraft (either by data-link or a Digital Voice Sysyem (DVS) broadcast). The controller should also be advised of the messages (though he won't preview them before they're transmitted). Alerts will appear in the Dedicated Alert Area discussed in Section 5.4. Depending on the size of the Alert Area, it may be possible to denote the alert as an 'ETIS ALERT'. There will be four types of ETIS alerts:

1.) Significant change in ETIS data.

ex: TMP DROP 1410
TMP 51 -5/4 min
(Temperature Drop Alert: Data collected at 1401; temperature 51° F; drop of 5° F in four minutes).

2.) Notification to controller to relay updates to non-DABS equipped aircraft (alerts will be broadcast via DVS).

ex: N375W/UPDATE
ALT 2997
(The altimeter setting for the airport is now 29.97 in. Hg)

3.) Unseccessful data-link attempt

ex: EA978/NO LINK
RVR 22R 30/33/31

(The controller will take appropriate action to test the link, and in the meantime provides the changes in RVR via voice channel)

4.) Any equipment or sensor failure

ex: RWY 15 ILS
INOPERATIVE

8.3 Manually Entered Data

To enter information into the ETIS System, it will be necessary to have the TIPS display/data entry unit switch to an ETIS input mode. (This will be for specific ETIS information (e.g. advisories); information such as runway changes will be automatically relayed to ETIS). ETIS input mode will be activated by a keyboard function. The controller will then have available a selection of preformatted massages with one or more parameters to be inserted.

ex: For a breaking action report, have displayed to the controller "braking action_____ (fair,poor,etc.) on runway_____, reported by a_____ (707,DC10, etc.). The controller types in the missing data.

The preformatted message selection will be presented (on a quick-look basis) on the display, or the controller will be provided with a hard copy numbered list from which he will make his choice. The elected message (s) will be displayed in the Preview Area. The controller will also have the capability to type in non-performatted messages, so long as they consist of the proper vocabulary. It will probably be desirable to provide the FD position with ETIS input capability (under direction of the Team Supervisor) or use the tower Input/Output Terminal.

8.4 Automatic Data Relay

The following information contained in TIPS will automatically be provided to ETIS, which will base its dispatches accordingly:

Aircraft Destination - This will allow arrival ETIS messages (see 4.2.3) to be compiled and dispatched according to which airport the aircraft is bound for (there usually are a sizable number of satellite airports within the terminal area).

Assigned Runway - This information will be necessary for ETIS to provide the appropriate RVR and wind data to a particular aircraft when there are multiple active runways.

Handoffs - Handoff from ARTCC to AR can be used to signal the dispatch of the initial arrival ETIS message. Handoff to FC can be used to trigger the dispatch of the final approach data message (see 6.1.1)

Active Runway Reconfiguration - All reconfiguration decisions, once validated by ATM/C, will be relayed to MTIS for inclusion in its advisory message. The resulting changes in assigned runways will be handled as described above.

IV. FINAL DISCUSSION

9.0 Areas for Further Work

The purpose of this study was to provide a preliminary investigation of what some of the requirements will be in an advanced ATC System. Many system interfaces and modifications were suggested, and quite a few assumptions were made. The feasibility of these proposals must be determined. Details of hardware capabilities can be provided only after actual development and testing of system components is done.

Much work is needed in the area of human factors. In this study, pilot and controller workload requirements were cursorily covered - they need to be evaluated more closely. Workload requirements will affect the design of cockpit and controller display units (the information provided, the required input functions, etc.) While controllers will retain active responsibility for ATC, their decision making process will be altered in the advanced system. The (psychological) effect of making decisions on computer decisions must be examined.

10.0 Summary

Of the system components discussed in Sections 3.0 and 4.0, TIPS is the furthest along in its actual development. A hardware model is presently being constructed. Specific details of its capabilities (proposed) were available. DABS has been under development since 1969; its data-link capabilities are known. What is lacking is the cockpit display specifications and surface coverage ability. Detailed specifications for ASTC and ATM/C are tenuous, they are in the concept stage and no testing has been done. Their general proposed functions were considered (some assumptions were made) in this study. ETIS is also in the concept stage, but its specifications were sufficient for the scope of this investigation.

Emphasis was primarily placed on TIPS display/data entry requirements and modifications. An important aspect of this investigation was what the tower controller interaction and interface would be in an advanced system. TIPS lends itself readily as an interface tool. TIPS is a 'passive' system, it displays data and provides for coordination among controllers. ASTC, ATM/C and ETIS are 'active' systems, they generate data. TIPS is a natural hub for interfacing these systems. ASTC and ATM/C

will use a display other than TIPS for traffic control data, and TIPS for other general information (assignments, schedules, etc.). It was proposed in this study to display ETIS information onTIPS, and use the TIPS system for coordination with others. DABS was considered as the primary communication link between aircraft and each system.

Modifications were proposed for TIPS based on the assumed requirements of ASTC, ATM/C and ETIS. The functions of ASTC, ATM/C and ETIS were obtained from the present design concepts; changes or augmentations were suggested only for interface purposes. For TIPS, enhancements were suggested to the design specifications for the test model being built by Lockheed Electronics Co. A summary of the modifications proposed in this thesis for implementation of TIPS in an advanced ATC system is presented below.

10.1 Suggested TIPS Modifications and Enhancements

Coordination will be required between TIPS, ATM/C ASTC, ETIS and controllers. The advanced system will be designed with this in mind. The TIPS concept now being developed for near term implementation will require enhancement for use in the advanced ATC system.

The TIPS modifactions suggested earlier in this thesis are summarized below (with appropriate sections for reference).

10.1.1 Display Requirements

General

- Commands (5.2)
- Pilot Response (5.3)
- Alerts (5.4)
- ETIS Information and Alerts (8.1,8.3)

Specific Information to be Displayed

- ETT in GC Pending List (5.9,6.2.1)
- ETT in Flight Plan Data (6.2.1)
- PDT in GC Active List (5.9)
- PDT in LC Departure List (5.9)
- ETA in LC Arrival List (5.9)
- ETG in GC Arrival List (5.9)
- Gate Assignment in GC Arrival List (6.3.3)
- Quick-Look Schedule (6.1.5)
- Clearance Confirmation (6.1.3,6.1.4)
- ETIS preformatted inputs (8.3)

Flagging

- General (5.5)
- Clearance Confirmation (6.1.3,6.1.4)
- Alerts (5.3)
- Avionics Capability (5.6)
- Command Message Status (5.7,App.C)

10.1.2 Functions and Capabilities

Flight Data

- ATM/C Interface (7.0)
- Cockpit display and filing (7.0)

Command Message Processing

- RELAY Quick Action (5.7)
- ACKNOWLEDGE Quick Action (5.7)
- PREVALIDATE Quick Action (5.7)
- OVERRIDE Quick Action (5.7)
- TO A/C Quick Action (5.7)

Traffic Control

- Missed Approach (MSAP Quick Action) (6.1.2)
- Handoffs (6.1.1)
- CLEARANCE Quick Action (6.1.3,6.1.4)
- Gate Hold (ETT) (6.2.1)
- Runway Reconfiguration (5.8)

Cueing or Triggering of Messages

Trigger Function	Triggered Message	
- CLEARANCE, (MSAP)	- Gate Assignment Request	(6.1.2, 6.1.3)
	- Notification to Departure Control	(6.1.4)
- Handoff	- ETIS Dispatch	(6.1.1)
	- Frequency Change	(8.4)
	- Coordinating notification to computer	(6.1.1)
- Emergencies, critical situations	- Alert	(5.4,8.2)

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VI APPENDICES

Appendix A: Present Controller Requirements for Tower and TRACON Positions

Abbreviations

Controller Positions

CD - clearance Delivery
FD - Flight Data
GC - Ground Control
LC - Local Control
CC - Cab Coordinator
TS - Team Supervisor (Tower)

DR - Departure Radar
DD - Departure Data
AR - Arrival Radar
TRACON AD - Arrival Data
TS - Terminal Control (Terminal Data, at Logan)
CI - TRACON Coordinator
TR - Team Supervisor (TRACON)
FL - Final Control

f.s. - Flight strip
fm. - from
FDEP - Flight Data Entry & Printout
TEL - Tower Enroute Control
TELCO - (intercom System)
TCA - Terminal Control Area
EFC/EAC- Expected Final Clearance (Time)/
Expected Appraoch Clearance (Time)

A.1 Tower Positions

A.1.1 Ground Control

Responsible for routing all surface traffic (aircraft and ground vehicles), excluding that on active runways. Provides information and advisories to departing aircraft as needed.

A.1.1.1 Information and Communication Equipment Available

RVR Display
Wind Direction Indicator
Wind Speed Indicator
Altimeter
Digital Clock
(ASDE)

List of runway assignments for aircraft categories

Flight Strips
TELCO
Radio
Visual Observations (Binoculars)

A.1.1.2 Information Required

Information Required	Provided by:
- location and identity of all vehicles (on airport)	visual, (ASDE)
- flight strip info: •ACID •A/C Type •latest ATIS for departures: •proposed departure time •assigned runway •a/c's initial contact location	f.s.
- gate or ramp for arriving aircraft	airline (via pilot)

- flight plan status	pilot
- ATIS type info (to update for for pilot, if necessary) • weather • field conditions • RVR	T.S.
- time	clock

A.1.1.3 Operational Duties

task or communication	method	receiver/ sender
maintains surveillance of airport surface	usual/ASDE	
- initial contact	radio	fm: pilot
•for dep:-expected a/c location (if unusual) noted on flight strip)	written	fm:f.s.
notes that initial contact was made	written	to: f.s.
•for arr: location confirmed by LC	verbal	fm:LC
receives ACID from A/C	radio	fm: pilot
- relays parking and ramp service requests	radio	fm: pilot to: service vehicle
- issues routing instructions	radio	to: pilot, ground vehicle
- coordinates crossing of active runways taxiing	verbal	to: fm: LC

for departures	method	receiver/ sender
- handoff from CD	passing of f.s.	fm: CD
- for push-back clearance, may note gate	written	to: f.s.
- relays advisories when necessary •weather •field conditions •RVR •Altimeter • etc.	radio	to: pilot
- flight plan status change	f.s., verbal radio	fm: CD or FD to: pilot
- modification of flight strip	passing of f.s	to: CD or FD
task or communication		
- arranges flight strips in sequence of proposed departure order	-	-
- responsible for achieving departure order before hand-off to LC (?)	-	-
- gives aircraft frequency change (for LC)	radio	to: pilot
- when aircraft arrives at run-up area or departure queue, hand-off to LC	f.s/verbal	to:LC

for arrivals	method	receiver/ sender
- handoff from LC	passing of f.s.	fm: LC
- contact by pilot (gives ACID)	radio	fm: pilot
- gate or ramp destination	radio	fm: pilot
- on delivery to gate or ramp, termination of control	written	to: f.s

A.1.2 Local Control (LC)

Controls arriving and departing aircraft in the vicinity of the airport and on active runways. Responsible for maintaining separation standards and for checking weather and clearance. Recommends to the team supervisor the selection of active runways. Works closely with cab coordinator.

A.1.2.1 Information and Equipment Available

RVR Display
RVV Display
Wind Direction Indicator
Wind Speed Indicator
Digital Clock

BRITE display
(wind Shear)
(ASDE)
(Altimeter

Flight Strips

TELCO

Radio (Mike, Headset, etc.)

Visual Observations (Binoculars)

A.1.2.2 Information Required	Provided by:
General	
-Info on A/C in vicinity of airport • identification • heading • speed • altitude • location • IFR or VFR	BRITE, pilot
-Location of A/C on or near active runways	visual, (ASDE)
-Visibility	visual
-Field conditions	T.S.
-RVR	indicator
-wind speed & Direction	indicator
-(wind shear)	(indicator)
-Altimeter	indicator
-ATIS code	T.S.
-Time	clock
-weather; NOTAMS	visual, advisories
For Departures:	
-Flight Strip Info • ACID • A/C type • Beacon Code • Proposed Departure Time • Requested Altiude • Route (1st fix)	f.s.
-Code of last ATIS broadeast received by A/C	pilot
For Arrivals:	**Provided by:**
-Flight Strip Info •ACID •Assigned Rwy •if A/C is heavy	handwritten f.s.

A.1.2.3 Operational Duties

task or communication	method	receiver/ sender
General:		
- check weather, visibility, field conditions, etc.	visual, NOTAMS, T.S.	fm: varied
- check operating capability of the BRITE display		
- write flight strips for over-flights	written	to: f.s.
- coordinates the crossing of active runways	verbal	to/fm:GC
- communicates/coordinates with FD (requests needed ARTS info. inputs	verbal	to: FD
Departures:		
- receives handoffs when A/C arrives at departure queue	passing of	fm: GC
- initial contact by pilot	radio	fm: pilot
- updates or relays any pertinent operating info: traffic, weather, advisories	radio	to: pilot
- issues take-off clearance (as soon as traffic warrants)	radio	to: pilot
- records departure time	written	to: f.s

task or commu.	method	r/s
- notifies TRACON of departure (gives ACID)	TELCO	to: DR
- receives acknowledgement	TELCO	fm: DR
- notes on f.s. that DR was contacted	written	to: f.s.
-(vectoring instructions, if necessary)	radio	to: pilot
-as soon as A/C is airborne, instructs pilot to contact DR (gives freq. change)	radio	to: pilot
-handoff to DR drops f.s. to DD by gravity tube	passing of f.s.	to: DD

also:

-coordinates the release of all IFR deps. from secondary runways	TELCO	to: DR
-aborted take-off: handled like an arrival		

For Arrivals

-quick looks & AR displays (monitors BRITE)	BRITE	fm. AR,FC
-receiver handoff	TELCO	fm. FC,TC or AR
-contacts pilot	radio	to: pilot
-pilot replies with ACID & approx. location	radio	fm: pilot
-updates and relays pertiment operational info. • RVR • wind, speed and direction • field conditions	radio	to: pilot

•altimeter •weather •traffic advisories •other advisories		
- issues necessary vectoring commands	radio	to: pilot
- issues clearance to land	radio	to: pilot
-landing status noted	written	to: scratchpad
- after touchdown, tells pilot where to turn off runway	radio	to: pilot
- gives routing commands until A/C is clear of all active runways	radio	to: pilot
- handoff to GC	passes f.s	to: GC
•informs pilot of freq. change	radio	to: pilot
- notifies Data Processor, which closes flight plan		

Arrivals

- missed approach is coordinated with TRACON	TELCO	to: AR,DR
• coordinates with A/C:	radio	to: pilot
-vectoring commands -freq. change for radar control		

A.1.3 Clearance Delivery (CD)

Transmits clearances for departing aircraft. Ensures that all aircraft have current ATIS information. Coordinates with departure data on aircraft not represented in computer. Assists flight data when necessary.

A.1.3.1 Information and Equipment Available — Provided by:

Flight Strips
Telco
Radio
ARTS monitor
Digital Clock

A.1.3.2 Information Required (CD)

-Departure Flight Strip info: — f.s.
ACID
A/C type/transponder
Computer ID
Beacon Code
Proposed Departure Time
Requested Altitude
Departing Airport
Route

(Assigned runway)

- Flight Status (IFR to VFR) — pilot
- Uncommon altitude requests — pilot
- Uncommon initial contact point (to GC) — pilot
- Weight restrictions — pilot
- ATIS Code — pilot, T.S
- Time — clock

A.1.3.3 Operational Duties

task or communication	method	receiver/ sender
- receives clearance request	radio	fm: pilot
- relays clearance to A/C (reads flight strip)	radio	to: pilot
- assigns runway	radio	to: pilot
-'flags' info. on flight strips: • uncommon altitude request • uncommon initial contact point (to GC) • weight restrictions • if A/C is heavy	written	to: f.s.
- prepares VFR flgiht strips	written	to: f.s.
• get beacon code	ARTS	to/ fm: FD
- prepares IFR to VFR flight strips	written	to: f.s
• get new beacon code	ARTS	to: FD
• notify DD	TELCO	to: DD
- ensures that all A/C have current ATIS	radio	to/ fm: pilot
- utilizes gatehold procedures, if necessary (pilots informed by ATIS)	radio	to: pilot
- gives pilot anticipated taxiing time	radio	to: pilot
- tells pilot to contact GC (gives freq. change)	radio	to: pilot
- handoff to GC	passes f.s	to: GC
-Assists FD when necessary		

A.1.4 Flight Data (FD)

Responsible for all FDEP and ARTS III activity required in the Tower (i.e., flight strip preparation, ARTS laypack entries, etc.) Receives and verifies clearances from ARTCC or other ATC facilities. Performs many of the Tower 'housekeeping' duties (changing the roll in the telautography, compiling statistics, etc.) No direct communication to aircraft.

A.1.4.1 Information and Equipment Available

FEDP
ARTS I/O Equipment
TELCO
Radio
Digital Clock
(Phone)

A.1.4.2 Information Required	Provided by:
- Flight Plans & Status	FDEP
- ARTS III general system area info.	ARTS monitor
- Clearances	ARTCC, other ATC Faces
- Time	Clock

A.1.4.3 Operational Duties

task or communication	method	receiver/ sender
- flight strips:remove, edit, mount, post & disseminate	FDEP	to: appropriate controller
- underline A/C in red, if heavy	written	to: f.s.
- receive departure clearances from other ATC facilities	phone	fm: TEC facilities
- verify ARTCC system flight plans	ARTS	to: ARTCC

- copies clearances from ARTCC & TEC facs	phone/written	fm: ARTCC,
-relay pertinent info.	radio	to: pilots
	verbal, written	to: appropriate controller
- hands off strips to CD	f.s.	to: CD
- assists CD, when necessary		
•prepare IFR to VFR flight strips	written	to: f.s.
•coord. with DD	TELCO	to/fm. DD
- general 'housekeeping'	-	-
•maintains telautograph		
•maintains FDEP		
•ensures that ARTS alpha/ numeric system is functioning; responsible for key pack entries		
- compiles statistical data (traffic count, etc.)	-	-
- maintains worksheet on ATC delays	-	-
- monitors & updates ARTS III general system area info.	-	-
- monitors ATIS info. & imputs	-	-

A.1.5 Cab Coordinator

Works closely with LC, but with other tower controllers when required. Coordinates tower activities with the TRACON. Maintains close surveillance of inbound traffic. Determines runway usage. Major responsibility is with arrivals, as compared to be with arrivals and departures. No direct contact with aircraft.

A.1.5.1 Information and Equipment Available

(LC equipemnt is available to the Cab Coordinator)

RVR Display	Brite Display
RVV Display	Altimeter
Wind Direction Indicator	Digital Clock
Wind Speed Indicator	(Wind Shear)
Flight Strips	
Telco	
Radio	
Visual Observations (Binoculars)	

A.1.5.2 Information Required	Provided by:
-Info on arrivals	
• (most important): location & ACID	BRITE
• speed	
• heading	
• altitude	
-visibility	visual
-field conditions	T.S.
-wind speed & direction	indicators
-weather	visual, advisories
-coordination info from Tracon	TELCO
-time	clock

A.1.5.3 Operational Duties

task or communication	method	receiver/ sender
General:		
- coordinates and directs the activities of all tower cab positions	verbal	to/fm: tower
- coordinates above with • VFR flights • advises CI of info. which will affect inbound operations: missed approach, runway conditions or closures, etc.	TELCO	to/fm: CI
- determines runway usage	verbal	to/fm: TS
LC Assistance		
- extracts arrival info.		
- maintains visual surveillance of all inbound aircraft	visual/ BRITE	
- prepares flight strips (for LC) for all arriving aircraft	written	to: f.s.
- assists LC in formating VFR departure clearances	verbal	to/fm: LC
- monitors VFR departures on radar	BRITE	
- coordinates VFR departures with TRACON	TELCO	to/fm: CI

A.1.6 Team Supervisor (TS)

Directs overall activity of the Tower. Makes final decisions and provides assistance in operational situations. Monitors operating status of equipment. Handles communication with outside agencies. Responsible for accuracy of ATIS information.

A.1.6.1 Information and Equipment Available

Generally: all the equipment in the tower

Specifically: Teleautograph
Telco
Telephones: Direct lines to relevant agencies (Fire Dept, Tug boats (Boston), et al)

A.1.6.2 Information Required

- all the conditions which affect operation of the airport:
  - -weather
  - -field conditions
  - -traffic
  - etc.
- status of equipment and instruments
- any pertinent info. requiring coordination within tower or between tower & TRACON

A.1.6.3 Operational Duties

task or communication	method	receiver/ sender
- supervisors overall tower activity (monitors & evaluates)	_	_
- provides assistance and decisions in operational situations	_	_

task or communication	method	receiver/ sender
- maintains proper discipline (of tower personnel)	—	—
- responsible for operational status of equipment; responds to outages	—	—
- assists in maintaining records of facility operations	—	—
- assists LC in determining visibility; responsible for recording and relaying the information	—	—
- depending on airport & fixed geometry, determines departure heading	—	—
- compensates for poor cab design, i.e., reads and relays telautography info, switches radio frequencies for controller, etc.	—	—
- coordinates between tower & TRACON	TELCO	—
- coordinates with CFR, police, coast guard, etc. during emergencies	telephone	—
- handles telephone/interphone calls from user agencies	phone	—
- formulates and tapes ATIS message (at least once per hour) and is responsible for its accuracy	tape-recorder	to: ATIS
- notifies all controllers of weather	verbal	to: Tower
- determines method of relaying meteorological information when the weather Bureau is inoperative		

task or communication	method	receiver/ sender
- institutes gate hold procedures, when required	_	_
- whenever primary runways change, insures that this info. is put on the telautograph	_	_
- designates the primary runways to be used for landings and takeoffs, and coordinates this info.	_	_
- moves about the cab, assisting any controller; frequently performs tasks for FD, CC positions	_	_

A.2 TRACON Positions

A.2.1 Arrival Radar (AR)

There are 2 or more arrival radar postions at major airports, each controller having responsibility for inbound aircraft within a given sector. Normally receives handoffs from ARTCC, and gives handoffs to FC or LC via the semiautomatic ARTS III computer system. Delivers aircraft to final approach (FC) by issuing vectors, clearances and instructions and observing aircraft positions on the ARTS plan view display (PVD). Supported by an arrival data (AD) position and the TRACON coordinator (CI).

A.2.1.1 Information and Communication Equipment Available

ARTS PVD and related Equipment
RVR panel
Wind Direction Indicator
Wind Speed Indicator

Digital Altimeter
Digital Clock
Maps & Approach Charts

TELCO
Radio
Flight Strips

A.2.1.2 Information Required

Information Required	Provided by:
- Info on arriving aircraft into TCA •ACID •type •beacon code •speed •altitude •heading •position •IFR or VFR •destination airport •previous fix •coordination fix •ETA at coord. fix	ARTS PVD, pilot, f.s. f.s.
- assigned runway or type of approach	f.s.

- traffic situation	ARTS PVD, TSR
- wind speed & direction	indicator
- altimeter	indicator
- ATIS code	(ARTS)
- weather	AD, CI, TSR
- time	clock
- RVR (to notify pilot)	indicator
- confirmation of radar contact	ARTS, pilot

A.2.1.3 Operational Duties

task or communication	method	receiver/ sender
- maintains surveillance within ATC sector and TCA in general. 'Quick looks' other positions	monitor	fm: ARTS PVD
- ascertains that the alpha/numeric system of ARTS is functioning		
- is aware of radar & ARTS III equipment limitations		
- recognizes radar deteriorations and rectifies promptly		
- receives handoff of aircraft into sector	ARTS	fm: ARTCC, AR or DR
- controls aircraft by issuing: •vector commands •clearances •instructions	radio	to: pilot
- on initial contact with arriving aircraft:	radio	to/fm: pilot

task or communication	method	receiver/ sender
- receives: • altitude report • ATIS code • PIREPS		
- sends: • altimeter setting • altitude instructions • RVR • wind info • assigned runway and/or type of approach		
- coordinates with AD flight strip: • note time of radar contact • assigned altitudes • note pilot's receipt of ATIS code and altimeter setting • note speed changes	verbal, f.s. written	to/fm: AD to: fs
- adheres to arrival sequence dictated by CI		fm. CI
- beacon check, if necessary	ARTS	to/fm: pilot
- position reports		
- handoff to other ARs, or TC (for secondary runway)	ARTS	to: AR, TC
- normally, handoff to FC	ARTS	to: FC
• notify pilot of freq. change	radio	to: pilot
• descend A/C to predetermined altitudes	radio	to: pilot
• 'quick look' FC position	monitor	to: ARTS
• ensure A/C info. is in ARTS	monitor	to: ARTS

- receives handoff of missed approach A/C from DR	ARTS	fm: DR
• coordination by CI	verbal TELCO	to/fm: CI

A.2.2 Departure Radar (DR)

There are 2 or more departure radar positions at major airports, each controller having responsibility for outbound aircraft within a given sector of airspace. Receives hand-offs from LC by automatic radar acquisition by ARTS. Delivers aircraft to departure fix for exit from the TCA by issuing vectors, clearances, and instructions and observing aircraft positions on the ARTS PVD. Hands-off departing aircraft to ARTCC via ARTS. Supported by Departure Data (DD) position and the TRACON coordinator (CI).

A.2.2.1 Information and Communication Equipment Available

ARTS PVD and related equipment	Maps & Charts
Digital altimeter	
Digital clock	
Telco	
Radio	
Flight Strips	

A.2.2.2 Information Required	Provided by:
- info on departing aircraft	ARTS, pilot, f.s.
• ACID	
• type	
• beacon code	
• speed	
• altitude	
• heading	
• position	
• proposed departure time	
• route (exit fix)	

- traffic situation		ARTS, TSR
- altimeter		indicator
- time		clock
- confirmation of radar contact		pilot, ARTS
- status on pending departures		tower

A.2.2.3 Operational Duties

	task on communication	method	receiver/ sender
same	- maintains surveillance of all aircraft within ATC sector and TCA in general. 'Quick looks' other positions	monitor	fm: ARTS PVD
	- ascertains that the alpha/numeric system of ARTS is functioning		
	- is aware of radar & ARTS III equipment limitations		
	- recognizes radar deteriorations and rectifies promptly		
	- use of pending departures	monitor	fm: ARTS
	- receives notification of departure	TELCO	fm: LC
	• acknowledges	TELCO	to: LC
	- receives flight strip from LC (to DD)	gravity tube	fm: LC
	- automatic radar acquisition of departing aircraft	ARTS	fm: LC

	method	receiver/ sender
- initial contact with aircraft receives: ACID	radio	fm: pilot
sends: radar contact assurance altimeter setting, if necessary	radio	to: pilot
- controls aircraft by issuing: •vectors •clearances •instructions	radio	to: pilot
- works closely with DD	verbal, f.s.	to/fm: DD
- coordinates departures from secondary runways	TELCO	to/fm: Tower
- handoff to other radar controllers within TCA	ARTS	to/fm: any radar controller
- on flight strips: • notes when radar contact is established • notes altitude assignments • notes handoff to ARTCC	written	to: f.s.
- notifies pilot of freq. change for handoff to ARTCC	radio	to: pilot
- handoff to ARTCC	ARTS	to: ARTCC

A.2.3 Final Control (FC)

Controls, merges traffic for approach to primary runway(s). Receives handoff from AR, delivers aircraft to LC at about 4 miles from end of runway by vectoring, while establishing final sequence and maintaining separation standards. Monitors ARTS PVD. Hands-off aircraft to LC via ARTS.

A.2.3.1 Information and Communication Equipment Available

ARTS PVD and related equipment

RVR panel

Digital clock

Charts

TELCO

Radio

A.2.3.2 Information Required — Provided by:

- Info. on arriving aircraft — ARTS PVD, pilot
  - ACID
  - type
  - beacon code
  - speed
  - altitude
  - heading
  - position
- type of approach — pilot
- traffic situation — ARTS PVD
- RVR (to notify pilot) — indicator

A.2.3.3 Operational Duties

task or communication	method	receiver/ sender
- maintains surveillance of all aircraft sector and TCA in general. 'Quick looks' other positions	monitor	fm: ARTS PVD
- ascertains that the alpha/numeric system of ARTS is functioning		
- is aware of radar & ARTS III equipment limitations		
- recognizes radar deficiencies and rectifies promptly		

- receives handoffs from AR or TC	ARTS	fm: AR, TC
- on initial contact by pilot receives: altitude report position report	radio	fm: pilot
sends: altitude instruction speed instruction	radio	to: pilot
- issues other necessary vectoring instructions or clearances	radio	to: pilot
- merges A/C into and establishes final sequence	radio	to: pilot
- maintains separation standards		
- gives pilot greq. change for LC	radio	to: pilot
- hands off to LC	TELCO	to: LC

A.2.4 Terminal Control (TC)

At Boston Logan, this position controls VFR flights into the TCA. Delivers aircraft to FC for primary runway landing or to LC for secondary runway landing. Uses ARTS III system and vectors aircraft in the same way as other radar controllers.

A.2.4.1 Information and Communication Equipment Available

ARTS PVD and related equipment	Digital altimeter
Wind Direction Indicator	Digital clock
Wind Speed Indicator	Maps & Approach Charts
TELCO	
Radio	
Flight Strips (handwritten)	

A.2.4.2 Information Required — Provided by:

-Info on arriving aircraft — ARTS PVD, pilot, f.s.
- •ACID
- •type
- •beacon code
- •speed
- •altitude
- •heading
- •position
- •destination

-Flight strip info, since handwritten (by TC), consists of
- •ACID
- •type
- •destination
- •altitude assignments
- •note on initial radar contact

-traffic situation — ARTS PVD, TSR

-wind speed & direction — indicator

-altimeter — indicator

-ATIS code — (ARTS)

-weather — CI, TR

-time — clock

-(RVR)

A.2.4.3 Operational Duties

task or communication	method	receiver/ sender
- maintains surveillance within ATC sector and TCA in general. 'Quick looks' other positions	monitor	fm: ARTS PVD
- ascertains that the alpha/numeric system of ARTS is functioning		
- is aware of radar & ARTS III equipment limitations		
- recognizes radar deteriorations and rectifies promptly		

A.2.5 Departure Data (DD)

Assists DR positions by handling FDEP related duties and entering ARTS keypack information. Ensures that DR position have appropriate and updated information. Performs DR functions, when necessary.

A.2.5.1 Information Communication Equipment

ARTS input equipment
(views DR PVD, if necessary)
FDEP, flight strips
Digital Clock
TELCO

A.2.5.2 Information Required	provided by:
- flight plan & status	FDEP
- info to distribute to DRs	
•flight strips	FDEP
•clearances	TR, CI
•departure sequences	TR, CI
DR requests	DR
•FDEP inputs	
•ARTS inputs	
•TELCO communication	
-Time	Clock

A.2.5.3 Operational Duties

task or communication	method	receiver/ sender
-assists DR, as necessary		to: any
•communication to other controllers or centers	TELCO phone, verbal	-
•ARTS key pack entries	ARTS	
•flight plan revision (IFR to VFR)	FDEP;written	to: ARTCC, f.s.
•makes handoffs, when required	ARTS	to: ARTCC

task or communication	method	receiver/ sender
- responsible for approaches to secondard runway(s)		
- VFR flights contact TC prior to entering TCA, for instructions	radio	fm: pilot
- receives necessary info. to prepare flight strip •ACID •type •destination	radio	fm: pilot
- confirms radar contact •notes on flight strip	radio written	to: pilot to: f.s.
-receives: altitude report •ATIS code •PIREPS	radio	fm: pilot
-sends: altimeter setting •altitude instructions (notes on f.s.) •wind info •assigned runway •(RVR)	radio	to: pilot
- controls aircraft by issuing: •vector commands •clearances •instructions	radio	to: pilot
- receives handoffs for secondary runway landings of aircraft from AR	ARTS	fm: AR
- responsible for most VFR flights <u>through</u> the TCA		
- hands-off large VFR aircraft to FC for primary runway landing •notifies pilot of freq. change	ARTS radio	to: FC to: pilot
-hands-off aircraft to land on secondard runway (VFR or IFR) to LC •notifies pilot of freq. change	(ARTS) radio	to: LC to: pilot

task or communication	method	receiver/ sender
- receives flight strips from tower	gravity tube	fm: LC
- distributes flight strips to appropriate DR	passing of f.s.	to: DR
- copies clearance and departure sequence from tower	TELCO	fm: Tower
- relays clearances and other pertinent info	TELCO, verbal	to: DR
- accepts departure info from satellite airports	(phone)	fm: satellite airpts
- 'house keeping' duties •responsible for FDEP printer (change strips) •change roll in telautograph		

A.2.6 Arrival Data (AD)

Assists AR position TC by posting flight strips, making and receiving intercontroller communication, and performing ARTS keypack manipulation. Executes other AR or TC duties, when necessary. (Known as Terminal Data Position, at Boston Logan).

A.2.6.1 Information and Communication Equipment

ARTS input equipment
(views AR or TC PVD, if necessary)

FDEP, flight strips

Digital Clock

TELCO

telautograph

phone

A.2.6.3 Information Required — provided by:

- flight plan & status — FDEP
- NOTAMS, weather — teleautograph
- info to distribute to AR, TC
  - flight strips — FDEP
  - weather advisories — teleautograph
- AR, TC requests — AR, TC
  - TELCO calls
  - ARTS inputs
  - FDEP inputs
- time — clock

A.2.6.3 Operational Duties

task or communication	method	receiver/ sender
- supports AR, TC positions: •posts flight strips •makes & receives TELCO calls •performs ARTS keyboard functions		
- receives flight strips from ARTCC	FDEP	fm: ARTCC
- removes & posts NOTAMS; weather	telautograph	
- assists AR in taking handoffs, when required	ARTS	fm(ARTCC)
- assists CI in forwarding info to LC	TELCO	to: LC
- advises ARTCC or TEC facility of the latest •EFC/EAC •runway & type of approach in use •during holding procedures, altitude of highest aircraft	phone	to: ARTCC
- coordinates for arrivals into satellite airports	phone	to: sat. aps

A.2.7 TRACON Coordinator (CI)

Establishes final arrival sequence and coordinates this information between controllers. Relays arrival information to CC; advisers TR of anyting which may affect the arrival flow of traffic. Relays more complex information between controllers.

A.2.7.1 Information and Communication Equipment

TELCO
Phones
(ARTS PVD of any radar controller)

A.2.7.2 Information Required	provided by:
- traffic situation (anything that affects it)	ARTS PVD
- any info requiring coordination within TRACON or with CC	verbal, TELCO

A.2.7.3 Operational Duties

task or communication	method	receiver/ sender
- determines final sequence of arriving aircraft	verbal	to: AR, TC
- relays information on aircraft arriving on the secondary runway(s)	TELCO	to: CC
- initiates outer clearance limits	verbal	to: AR,TC
- establishes route for overflights, when necessary	verbal	to: radar ctlr
- advises TR of any info which may affect the arrival flow of traffic	verbal	to: TR

task or communication	method	receiver/ sender
- coordinates with other TRACON/TOWER positions as required	verbal, TELCO	to/fm: any
- uses PVD of radar controller when coordinating with that position		

A.2.8 TRACON Supervisor (TR)

Responsible for the operation of the TRACON. Provides necessary decisions and coordination in operational situations. Responds to equipment outages and airport emergencies.

A.2.8.1 Information Communication Equipment

TELCO
phones
(radio)
(ARTS PVD of any radar controller)
telautograph

A.2.8.2 Information required	provided by:
- anything which will affect the flow of traffic	varied
- status of equipment and instruments	indicators
- any pertinent information requiring coordination, with TRACON or between TRACON and Tower or ARTCC	TELCO, phone

A.2.8.3 Operational Duties

task or communication	method	receiver/ sender
- responsible for overall operation of the TRACON		
- makes necessary decisions in operational situations		
- maintains proper discipline (of TRACON personnel)		
- responsible for operational status of equipment, responds to outages		
- monitors ARTS III general system data for accuracy		
- assists in maintaining records of facility operations		
- performs necessary coordination:		
•within TRACON	TELCO, verbal	
•with tower	TELCO	
•with ARTCC	phone	
•with Weather Bureau	phone	
- responsible for flow control; informs		
•ARTCC of:	phone	
•runway usage		
•acceptance rate		
•EFCIEAC's		
- issues, receives, and disseminates flow control restrictions		
- handles routine phone falls from user agencies		
- coordinates with TS to evenly distribute delays between arrivals & departures, when saturation occurs		

Appendix B: TIPS

B.1 Operation of the Quick Action Data Entry Unit

Presented in Figure B.1 is a depiction of the controller following the necessary procedure to have the flight plan of ACID6 read out, which in this case requires the pushing of 3 buttons.

View A - The display before any controller action; ACID6 is in the left list

View B - The controller identifies the row that ACID6 is in by pushing the adjacent button. Lines are drawn above and below the row. If the incorrect row had been selected, the controller would need only push the proper button and the lines will form next to it.

View C - ACID6 is selected by depressing the button directly beneath its column. ACID6 is then enlarged and brightened, while the quick action functions now available are displayed in the legend area next to the quick action buttons.

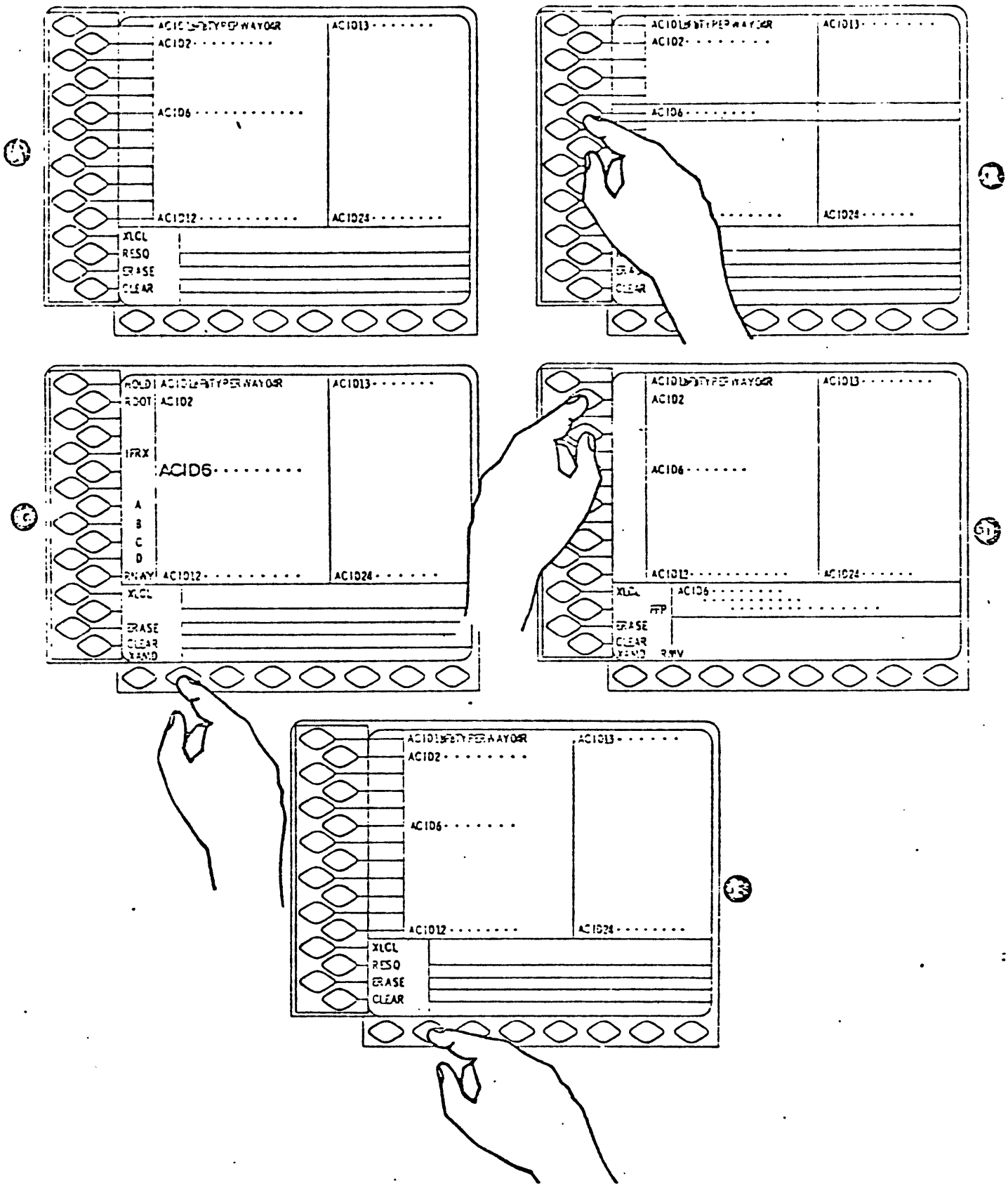

FIGURE B.1 TIPS QUICK ACTION DATA ENTRY UNIT AND ITS OPERATION

View D - The controller pushes the button for 'READOUT' (RDOT) and the flight plan for ACID6 appears in the Readout Area. The list of quick action functions which required pre-selection of any ACID row disappear, and ACID6 returns to its normal size.

View E - The flight plan is removed from the Readout Area by depressing the 'REMOVE' (RMV) button. The displayed quick action functions which apply to a flight plan in the Readout Area disappear. Instead of RMV, the controller could have selected another ACID by starting the sequence from View B.

B.2 TIPS Functions

B.2.1 General Inputs

The general TIPS controller inputs will be

- Flight Plan readout requests
- Transfer of flight responsibility
- Entry of flight data
- Resequencing of lists
- Amendment requests
- Deletion of flight data (for termination of flight)
- Cancelling existing flight plans
- Entry of local weather and status information

Inputs of a supervisory nature will be entered via an Input/Outut Terminal in the tower:

- Controller/display reconfiguration
- Enter weather data
- Enter status data
- General system information

B.2.2 Quick Action Functions

B.2.2.1 Common To Tower Position

READOUT (RDOT)

This action will cause the flight plan of the identified flight to be displayed in the readout area. Full or abbreviated flight plans will be read out; the particular adaptation chosen will depend on controller/facility needs. If the flight plan cannot be completely displayed, the characters "MORE" will appear at the end of the last line in the Readout Area. Manual entry of FULL FLIGHT PLAN quick action will cause the next segment to be displayed. For CD and FD, "RDOT" will be implied when an ACID is selected.

REMOVE (RMV)

This action will cause the Readout Area to be cleared.

FULL FLIGHT PLAN (FFP)

This action will result in:

1) the full flight plan being displayed in replace of an abbreviated one
2) the remainder of a full flight plan being displayed if more than 4 lines is required.

Additional entries of FFP will cause either subsequent segments of the flight plan to be displayed or the first segment to be redisplayed

ERASE (ERASE)

This action will cause the computer Response Area to be cleared.

RESEQUENCE (RESQ)

This action will permit the reordering of any flight data entry in a list (inhibited if the list is in chronological or alphanumeric order). The reordering will be executed by the controller selecting the ACID to transfer, then depressing the "RESQ" switch, and finally selecting the ACID to which the first selection is to follow.

MORE/RETURN

When paging of a displayed list is required, the notation "MORE" will appear as the last entry in the list. Selection of the button across from "MORE" will cause the next page of entries to be displayed. "MORE" will remain in each list until the last page is reached. At this point, "RETURN" will appear in its place. Activating the button will cause the first page to be returned.

B.2.2.2 Ground Control

TRANSFER FOR AMENDMENT (XAMD)

This action will be used to route to CD or FD or both (depending on Tower adaptation) the identification of a departure flight which requires a flight data modification. There will be two permissable input sequences.

1) The flight listed in the Readout Area will be sent (if no other ACID is selected).
2) If the Readout Area is blank, the ACID must be selected from the Departure List

CANCEL IFR (IFRX)

This action will change a flight plan displayed in the Readout Area from IFR to VFR.

HOLD/RELEASE (HOLD)

This action will indicate that an arriving or departing aircraft is not actively taxiing. It causes a site-adaptable character (e.g., "H") to be displayed as the fourth character of the runway field. If the action is taken again on the flight, the hold indicator will be removed and the intersection departure designator restored

(see next quick action).

INTERSECTION DEPARTURE

This action will be used to indicate the runway intersection assigned to a departing flight. The following will result:

1) A single character designator will be displayed as the last character in the assigned runway field.

2) The designator will remain after handoff to LC.

3) A subsequent selection of another runway intersection will cause the previous designator to be overwritten.

TO LOCAL (XLCL)

This action will cause the departure flight data of the selected flight to be handed off to LC. The following will happen:

1) If a flight plan amendment is in progress, XLCL action will be rejected

2) The flight data will be transferred to the Departure list of the LC

3) The entry will be deleted from the GC Departure List, and the list reorded if necessary.

4) If the flight plan is in the Readout Area, it will be cleared.

RUNWAY MODIFICATION (RWY)

This action will enable the controller to:

1) enter a runway number into a blank runway field

2) modify the presently displayed runway field

TERMINATE (TERM)

GC will take this action on an arriving flight after he has completed his control functions (delivery to the ramp area or assigned gate). The following will take place:

1) The entry will be deleted from the Arrival List, and the list reordered as necessary

2) If the flight plan is in the Readout Area, it will be cleared

3) Flight data for the terminated flight will be purged from the tower subsystem internal storage

B.2.2.3 Local Control

Same quick action functions as GC:

- TRANSFER FOR AMENDMENT (XAMD)
- RUNWAY MODIFICATION (RWY)
- CANCEL IFR (LC position displays-beacon code)

TO GROUND (XGND)

This action will be used to handoff arrival data to GC. The selected flight data will be deleted from the LC Arrival List and transferred to the GC Arrival List. Two input sequences will be possible:

1) If an ACID is identified, the action will apply to it

2) If no identification is entered, the top entry of the list will be transferred

MISSED APPROACH (MSAP)

This action will return the flight to the TRACON for resequencing. The flight data entry in the Arrival List will be deleted and the list reordered. After the flight is resequenced, it will be re-entered into the LC Arrival List.

TO TRACON (XTRC)

This action will be used to handoff a departing flight to the TRACON. The associated flight data will be deleted from the Departure List, and the List reorganized. Two input sequences will be possible.

1) If the flight is identified, the action will apply to it

2) If no identification is entered, the action will apply to the entry at the top of the Departure List

B.2.2.4 Clearance Delivery Q.A

Same quick actions as GC and/or LC:

- CANCEL IFR (IFRX)

TO GC (TO GC)

This action shall cause the flight data displayed in the Readout Area to be transferred to GC. The following will take place:

1) The Readout Area will be cleared
2) The associated ACID will be deleted from the List, and the List reorganized
3) The flight data will be transferred to the Pending List of GC.

B.2.2.5 Flight Data

FD will have the same quick action functions available as CD.

Appendix C: Command Message Formats and Examples

General

It may be necessary to include ACID, time and response with each message.

ex: 1)	DL123: CLB/270 20:30/21:35	DL123, climb to 27,000 feet Message displayed to controller at 20 min. 30 sec into the hour; to initiate the command at 21 min 35 sec.
2)	DL123: CLB/270 A	Pilot response (A): message acknowledged

There are other methods: pilot reply could be in pilot response area, ACID could be implied if command is displayed in the appropriate data block, etc.

Air Control Message Example

The main goal is to have the messages in a concise format so they won't take up much space on the controller or cockpit display. Some examples of the message types are given below (without ACID or time); the exact format will depend on hardware design and user preference.

Displayed	Voiced
DSCD/140	descend and maintain an altitude (14,000)
CLB/180	climb and maintain an altitude (18,000)
X/FIX ↟ 300	cross a fix, at or above an altitude (30,000)
RT/290	next turn right to a heading (290 degrees)
→VOR	proceed to a VOR
SPD/210	(reduce, increase) speed to 210 knots
X/WAYPT @ 1510Z	(for RNAV): cross a way point at a given time
CLR/LND	cleared to land
EXCT/MA HDG/220	execute missed approach; take up initial heading (220 degrees)
CTC/TWR 119.1	contact tower on 119.1

Depending on available display space, symbols may be desirable (i.e., ↑for climb, ↓for descend, etc.).

Surface Control Messages

Surface control messages will be of the same basic format as the air control messages; the pilots will use the same cockpit display for both. Some examples are given below.

Displayed	Voiced
SLOW	Potential hazard; proceed slowly
STOP	Stop
RT/D HLT/SHT	Next turn is right onto taxiiway D, hold short of next hold bar
CONT/W PROCEED	Continue on taxiway W; next intersection clear, may proceed at safe speed
CLR/TKOF HDG/220	clear for takeoff; initial heading 220 degrees
CTC/DEP 122.9	contact Departure Control on 122.9
ABORT/SLOW	your departure is aborted; you will be routed back to the taxiway system