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TOWER-RELATED MAJOR SYSTEM DEVELOPMENT PROGRAMS

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

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16. Abstract

This report is devoted to the present and near future states of the tower cab environment, addresses those MSDP systems which may have an impact on the current tower cab environment, systems and/or operations. The systems included are: Discrete Address Beacon System (DABS), Airport Surface Detection Equipment III (ASDE III), Tower Airport Ground Surveillance (TAGS), Terminal Information Processing System (TIPS), ARTS II and ARTS III enhancements, Flight Service Station Automation (FSSA), Vortex Advisory System (VAS), Wake Vortex Avoidance System (WVAS), Wind Shear Detection system (WSD) and Microwave Landing System (MLS). Each system is described in terms of its functional objectives, planned equipment, interfaces with other systems and with controllers, failure modes, and current development/deployment status.

This report is a continuation of report No. FAA-EM-77-10/(DOT-TSC-FAA-77-19) entitled: "Characterization of Current Tower Cab Environments," dated November 1977 (240 pages).

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PREFACE

This report was prepared under Project Plan Agreement FA-744, "Major Systems Development Integration Analysis", sponsored by the Federal Aviation Administration, Office of Systems Engineering Management. It documents the second phase of a three-phase effort to study the impact on the tower cab environment of introducing Major System elements* into the CONSUS ATC system.

The authors wish to acknowledge the cooperation of many FAA personnel, especially the project managers of the systems reported herein and members of their staffs, as well as others from OSEM, SRDS and NAFEC who contributed time and energy in reviewing the material presented here.

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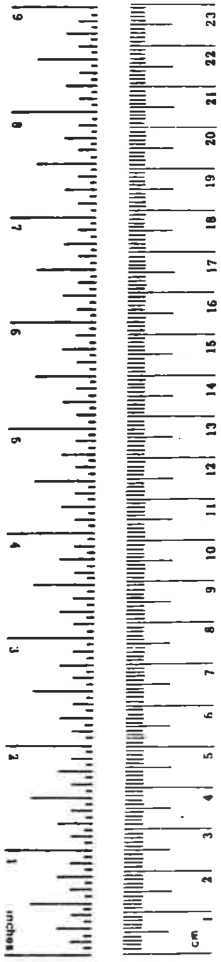
* Systems formerly termed 'UG3RD systems' or 'UG3RD generation systems' are now and henceforth referred to as 'Major System Development Programs (MSDP's).'

METRIC CONVERSION FACTORS

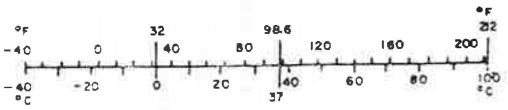
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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FOREWORD

This report should be read in conjunction with Report No. FAA-EM-77-10, "Characterization of Current Tower Cab Environments," November 1977. This is the second in a series of three interim reports culminating in a final report on the subject of tower-related systems integration analysis.

The first interim report constitutes chapters 1 through 5 of the final report and characterizes the current tower cab environment covering such topics as allocation of functions and equipment to tower positions, airspace surveillance data in the tower, surface surveillance, flight data handling, air/ground communications, data processing and display systems, weather-related systems, and landing systems.

This report, which constitutes chapters 6 through 11 of the final report, addresses those MSDP systems which may have an impact on the current tower cab environment, current systems, and/or operations. Included are Discrete Address Beacon System (DABS), Airport Surface Detection Equipment III (ASDE III), Tower Airport Ground Surveillance System (TAGS), Terminal Information Processing System (TIPS), ARTS II and ARTS III Enhancements, Flight Service Station (FSS) Automation, Vortex Advisory System (VAS), Wake Vortex Avoidance System (WVAS), Wind Shear Detection System (WSD), and the Microwave Landing System (MLS). Each system is described in terms of its functional objectives, planned equipment, interfaces with other systems and with controllers, failure modes, and current development/deployment status.

Together the first two reports form the foundation for the tower systems integration analysis, which will be the subject of the third and final interim report.

GLOSSARY

AART	Air Traffic Service
ACID	Aircraft Identification
ADU	Azimuth Distribution Unit
AFCS	Automatic Flight Control System
AMA	Airport Movement Area
AMPS	ATCRBS Monopulse Processing System
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASDE	Airport Surface Detention Equipment
ASP	Office of Aviation System Plans
ASR	Airport Surveillance Radar
ASTC	Airport Surface Traffic Control
ATC	Air Traffic Control
ATCAC	Air Traffic Control Advisory Committee
ATCRBS	ATC Radar Beacon System
ATIS	Automated Terminal Information System
AWOP	All-Weather Operations Panel
BDAS	Beacon Data Acquisition Subsystem
BITE	Built-In Test Equipment
BRITE	Bright Radar Indicator Tower Equipment
BTL	Beacon Tracking Level
CA	Conflict Alert
CD	Clearance Delivery; Common Digitizer
CDR	Continuous Data Recording (sometimes: Critical Data Recording)
CFA	Centerfield Anemometer

GLOSSARY (CONTINUED)

CMA	Central Memory Access
CPM	Central Processor Module
CRA	Computer Response Area
CW	Continuous Wave
DABS	Discrete Address Beacon System
DDAS	Decoding Data Acquisition System
DEDS	Data Entry and Display Subsystem
DEU	Display Enhancement Unit
DLS	DME-based Landing System
DME	Distance Measuring Equipment
DP	Display Processor
DPS	Data Processing Subsystem
DPSK	Differential Phase Shift Keying
DSC	Digital Scan Conversion
ELM	Extended Length Messages
FD	Flight Data
FDEP	Flight Data Entry and Printout
F&E	Facilities and Equipment
FP	Flight Plan
FRSB	Frequency Referenced Scanning Beam
FSS	Flight Service Station
GC	Ground Control
GFWS	Gust Front Warning System
GHz	GigaHertz
GTOW	Gross Takeoff Weight

GLOSSARY (CONTINUED)

GWVSS	Ground-Wind Vortex Sensing System
IATA	International Air Transport Association
IBAG	Interface Buffer Adapter Generator
ICAD	International Civil Aviation Organization
ICM	Interfacility Communications Multiplexer
IFALPA	International Federation of Air Line Pilots Associations
IFR	Instrument Flight Regulations
ILS	Instrument Landing System
IOP	Input-Output Processor
IOT	Input-Output Terminal
IPC	Intermittent Positive Control
LAWRS	Limited Aviation Weather Reporting Service
LS	Local Control
LDV	Laser Doppler Velocimeter
LLLTV	Low Light Level Television
MDBM	Multiplexed Display Buffer Memory
MLS	Microwave Landing System
M&S	Metering and Spacing
MSAW	Minimum Safe Altitude Warning
MTBF	Mean Time Before Failure
MTD	Moving Target Detector
MTTR	Mean Time To Repair
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NOTAMS	Notices to Airmen

GLOSSARY (CONTINUED)

NU-BRITE	New BRITE
NWS	National Weather Service
PEM	Position Entry Module
PJS	Pressure Jump Sensor
PPI	Plan Position Indicator
PSB	Pilot Self Briefing
PSM	Peripheral Switch Module
PDV	Plan View Display
RBS	Radar Beacon System
RBTL	Radar and Beacon Tracking Level
RDAS	Radar Data Acquisition Subsystem
RDBM	Remote Display Buffer Memory
RF	Radio Frequency
RFDU	Reconfiguration and Fault Detection Unit
RMD	Runway Monitor Display
RTCA	Radio Technical Commission for Aeronautics
SCMLS	Small Community MLS
SMD	System Monitor Display
SRAP	Sensor Receiver and Processor
SRDS	Systems Research and Development Service
STOL	Short Takeoff and Landing
TAGS	Tower Automated Ground Surveillance
TCA	Terminal Control Area
TCDD	Tower Cab Digital Display
TDM	Time Division Multiplexing
TDP	Tower Display Processor

GLOSSARY (CONTINUED)

TDS	Tower Display Subsystem
TFDH	Terminal Flight Data Handling
TFDP	Terminal Flight Data Processor
TIPS	Terminal Information Processing System
TRACAB	Terminal Radar Cab
TRACON	Terminal Radar Control
TRDP	TRACON Display Processor
TRDS	TRACON Display Subsystem
TRSB	Time Reference Scanning Beam
TWT	Traveling Wave Tube
VAS	Vortex Advisory System
VFR	Visual Flight Regulations
VSC	Video Scan Conversion
WPL	Wright-Patterson Laboratory
WSDS	Wind Shear Detection System
WVAS	Wake Vortex Avoidance System

6. AIRSPACE SURVEILLANCE AND AIR/GROUND COMMUNICATIONS

6.1 DISCRETE ADDRESS BEACON SYSTEM (DABS)

The Discrete Address Beacon System[1] combines the functions of surveillance and communications and can become a conflict-avoidance system with the addition of Intermittent Positive Control (IPC) capability.[2] Surveillance is carried out by means of interrogation messages sent uniquely to each aircraft being tracked. As a by-product of these discretely-addressed interrogations and replies, there becomes available a digital data-link of reasonably large capacity. The IPC process makes use of both the surveillance data and the data-link facility.

6.1.1 System Description

The interactions between the Tower Cab and DABS will be only indirect, probably via ARTS, hence there is a need here for only a cursory description of DABS.

Each DABS equipped aircraft will have a transponder which responds to both ATCRBS and DABS interrogations. The transponder will be hard-wired with a unique identifying code, or address. When it is interrogated by DABS, it will respond only to messages containing its code (messages said to be addressed to it), while ignoring all others, including ATCRBS interrogations. The DABS processor will keep track of the position of each aircraft and will schedule interrogations so that no two will interfere with each other.

The discrete address feature also makes it possible to use the interrogation process as an upward data link. The DABS message design includes a field for data to be passed through the transponder for ATC, IPC, or other use. The down-link capability is provided in a symmetrical way. In addition, a provision is made for Extended Length Messages (ELM) if they should prove worthwhile.

Thus, the DABS will supply to the ATC system both high-quality surveillance data and also a digital data-link capability which can be used for traffic control and, with the necessary processor attached, for IPC, as well.

6.1.2 System Integration and Interfaces

6.1.2.1 Interface Between DABS and ATC Systems - The current plan[3] for the use of DABS calls for digital communication paths between the DABS site processor and the processor at the nearby ATC site, ARTCC or TRACON. The surveillance information will flow from DABS to ATC along one high capacity path and ATC message data for and from the data-link will flow along another. There will, of course, have to be modifications and additions to the ARTS software to generate data-link messages and to react to the responses. These ARTS modifications will form the essential DABS/Tower cab interface.

6.1.2.2 Interfaces Between DABS and Controllers - Although DABS itself will not interface with controllers (in the sense of their having to operate a DABS console or monitor a DABS display), it will augment other systems in such a way as to reduce requirements for ground-air and air-ground communications and increase the reliability of the information available to controllers. The increased reliability will tend to increase the confidence the controller has in his displayed information and thereby reduce the stress under which he operates.

The digital data link capability of DABS will make possible a number of system developments which may have an impact on tower jobs. Chief among these are the automation of control-message generation and transmission, on the one hand, and IPC, on the other. IPC, for which DABS is a prerequisite, will back up controllers' conflict prediction capability, particularly with respect to VFR aircraft and will add an automatic command when the aircraft has not responded to the controller. Other systems are being developed which will tend to increase the controller's communications workload in the absence of a suitable data link; some of these are Wake Vortex Advisory System (WVAS), Wind Shear Advisory System (WSAS) and Tower Automated Ground Surveillance (TAGS). Even the Microwave Landing System (MLS) may eventually be included.

These developments built around the DABS capabilities are generally expected to lighten controllers' workloads by relieving them of the tasks of transmission of advisory and command messages. There are inherent dangers in this process, however. The controller must be informed of advice and commands that are automatically transmitted to aircraft in order to monitor the system operation, to maintain control of the operation, and to provide manual backup in case of system failures. Thus there will be a tendency to add more data to already crowded displays, or to add more displays to already crowded consoles. This problem will be addressed in greater detail in this report in connection with the systems providing tower displays and consoles.

6.1.3 Failure Modes

The DABS design contains elaborate provision for preventing, detecting, and dealing with failures. These include the use of highly reliable components and redundant equipment, continuous performance measurement and evaluation, and a network of sensors with overlapping coverage. The cumulative result is that there will be a vanishingly small probability that the controller will see the effect of a DABS failure. In that unlikely event, the ATC system would of necessity revert back to the manual mode.

6.1.4 System Status

Three engineering models of DABS sensors are currently being procured from Texas Instruments, Inc. They will be installed at NAFEC, Philadelphia and Elwood, N.J. and used in a series of tests[4] to develop the final design of the system. The first of the sensors is due in October of 1978 with the others following at three-month intervals. It is planned to have the ATC interface developed by mid-1979 and the so-called Technical Data Package ready for delivery to Airways Facilities by mid-1980.

Clearly, procurement of a system such as DABS will take a number of years, so any large-scale deployment will occur slowly; DABS, then, can be regarded as a system for 1985 and beyond.

6.1.5 Issues and Comments

The development of DABS has been controversial from the start and remains so now. There are many facets to the controversy ranging from technical to financial and political. There seems to be little question at this point that a fully deployed and operational DABS would provide enormous benefits to the ATC system and its users. The cost to reach such a state, however, is felt by many to be prohibitive. This cost includes the value of the current investment in ATCRBS, the cost of the DABS tower equipment, the cost of the DABS avionics, and the costs involved in modifying the ATC system to use DABS. The avionics cost, in particular, is an obstacle since it would be borne by the users of the system, presumably.

If the system were to be authorized and deployment were to begin, there would have to be a relatively long transition period between all-ATCRBS and all-DABS, if such a final state were ever achieved. Despite the exceptionally clever and sophisticated design of DABS, there would be a great deal of uncertainty and confusion on the part of the users and the controllers, especially in the early stages. Careful planning and education would help smooth the changeover, but there will inevitably be unforseen problems.

The data-link which comes with DABS is held to be a great advantage of the system and a boon to the ATC system in general. It is certainly important, but there is too little thought being given to its eventual form and relation to the rest of the MSDP's.

Thus, there are three issues which must be faced in regard to DABS: cost, transitional problems, and integration into the rest of the ATC system.

6.2 ATCRBS MONOPULSE PROCESSING SYSTEM (AMPS)

In the DABS design, RF radiation time is shared between DABS and ATCRBS. To provide DABS with enough time to carry out all of its functions, the ATCRBS share is set at around 25 percent. The effect of this reduction is to cut down the number of ATCRBS replies received from a target from about twenty to about five as the beam passes it. Since the current target detection algorithm used in ARTS and the Common Digitizer (CD) will not work with so few hits, a new scheme has had to be developed. The scheme proposed with AMPS uses monopulse tracking, wherein the return from each pulse of radiated energy gives information on both range and angular distance from the centerline of the receiving antenna. Thus, a single return is sufficient to determine position, although in practice, three or four returns are averaged to insure accuracy.

6.2.1 System Description

Three groups are working on the AMPS, each with its own point of view. The system being built by MIT Lincoln Laboratory and the FAA Detection Systems Branch (ARD-240) will use the latest, most sophisticated design and will be a mobile unit mounted in a van. It will be operated under varying conditions in many parts of the country to test for environmental and interface effects in actual working surroundings. In use, the van is parked as near the transmitting antenna as possible and the receiving antenna is aligned and synchronized with it. Triggers are picked off from the transmitter and used to synchronize the AMPs receiver, whose output can be recorded on tape for later analysis.

In the meantime, Texas Instruments, Inc. is building a very similar device and packaging it as part of the DABS site equipment. This receiver will be integrated into the rest of the system and tested for compatability and performance during DABS development.

The third version of AMPS is being built for the Terminal Branch, Engineering Section by UNIVAC and will be combined with a Moving Target Detector (MTD) into a unit which is called the SRAP II, in reference to the Sensor Receiver and Processor (SRAP) being developed for the Enhanced ARTS III program (See Section 9.2.1.1.1). The SRAP II will be used at NAFEC in a program to develop and optimize the ARTS software involved with use of this equipment.

6.2.2 System Integration and Interfaces

The AMPS equipment can be used as part of the ATCRBS alone or as part of the DABS, where it handles the ATCRBS portion of the processing. If used alone, it consists of a new (receiving) antenna, a multi-channel receiver, and a digitizer-processor. The output of the processor is sent by phone line to the ARTS (or ARTCC) processor for use. If used with DABS, it consists of the receiver and digitizer-processor, whose output is used at the DABS site to develop the final output to the ATC processors.

All of these interfaces and interactions are being developed and tested in the programs described above.

6.2.3 Failure Modes

The failure handling provisions of ATCRBS and DABS will apply to AMPS, as well. Chief among them are a wide-spread redundancy of functional units.

6.2.4 System Status

Since AMPS is a necessary part of DABS, it will be developed no slower than the rest of DABS, but since AMPS used alone could provide a relatively inexpensive upgrade of ATCRBS, it may be developed faster. Work is going forward on all three versions, with the UNIVAC/ARD-122 version expected to be delivered to NAFEC in August or September of 1977. Development work and preparation of the technical package will take some time, but money could be provided by Airways Facilities for procurement as early as FY 1979.

6.2.5 Issues and Comments

The AMPS program looks good from many points of view. It has support from both the advocates and opponents of DABS as well as those who take no sides but want better surveillance data, however obtained. If AMPS fulfills its promise, it could well have a future regardless of how DABS goes. Its integration into the ATC system should be particularly easy since it makes no demands on the aircraft owners and few on the ARTS or NAS systems.

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7. SURFACE SURVEILLANCE SYSTEMS

7.1 INTRODUCTION

7.1.1 Motivation for New Equipment

As discussed in Section 5.2, the chief problems with ASDE-2 were (a) poor ASDE bright display quality, (b) poor map definition by ground clutter, (c) maintenance difficulties and (d) poor performance in heavy rainfall conditions. Improvements to ASDE-2 such as the NU-BRITE display and Display Enhancement Unit (DEU) will solve items (a) through (c). However, little can be done to ASDE-2 to improve rainfall penetration. This performance is determined by the antenna beam shape, the radar operating frequency (24 GHz)and the radome shape. Modification of these elements is such a major undertaking that a new radar development would be preferrable.

If only the 12 existing ASDE-2's were required, their poor rainfall penetration would not likely prompt a new system development. However, with the introduction of Category IIIa landing, the deployment of MLS and the increase in low IFR traffic, recent analysis indicates the need for 37 ASDE's by 1985[1]. For this reason the FAA Engineering and Development program for Airport Surface Traffic Control (ASTC) is in the process of developing a new ASDE (ASDE-3).

Like ASDE-2 (See Section 5.2), ASDE-3 will improve the capacity of Local Control in low visibility conditions. It will restore his capacity to nearly that in good visibility conditions. However, while ASDE-3 will help Ground Control, it will not restore his capacity to that in VFR conditions. This is due to his continued reliance on pilot position reports to obtain the identity of the radar targets and to improve target detection, by knowing where to look for the target. However, despite this reduced capacity, it has been estimated that two ground controllers can handle 65 to 85 operations per hour with ASDE in bad cab visibility.

This capacity enables Ground Control to handle operations through the 1980's at all but four to nine airports.[2] At these airports the Ground Control voice channels will saturate, thus affecting capacity, delay, and safety. Identity is required on the radar targets to eliminate the need for pilot position reports and improve target detection. A system for adding identity (termed Tower Automated Ground Surveillance-TAGS) is under development by the ASTC program. TAGS would be deployed to the four to nine airports for which ASDE-3 is inadequate.

7.1.2 ASTC Program Overview

The ASTC program formally began in 1972 with a basic system requirements analysis. The requirements analysis indicated a need for (a) improvements to ASDE-2 for the near term, (b) the wider deployment of a new ASDE-3, and (c) the development of a system for providing flight identity on aircraft targets, TAGS. The program proceeded with detailed requirements work and specification preparation for ASDE-3. Plans call for the development and operational evaluation of an ASDE-3 engineering model prior to a production procurement. The schedule for ASDE-3 is given in Table 7.1-1. The program also proceeded with TAGS system studies and sensor feasibility analysis and test. This phase of the ASTC program is lagging ASDE-3 development, but is still in progress. Plans call for the development and operational evaluation of a TAGS engineering model prior to production procurement. The TAGS schedule is given in Table 7.1-1.

7.1.3 System Description

This section describes ASDE-3 and the most promising TAGS system concept. In addition, the TAGS alternative concepts under consideration are discussed. The purpose is to describe the essential elements which should be considered in integrating the other MSDP elements. The functional capabilities, cab equipment, system layout, and subsystem characteristics are described. In addition, comments on anticipated integration problems are made.

TABLE 7.1-1. ASTC PROGRAM SCHEDULE

ASDE-3	Completion Date
Engineering Model	
o Contract Award	May 31, 1977
o Installation for Evaluation	October 1978
o Operational Evaluation	March/April 1979
Production Procurement*	
o First 10 Units	FY 1980
o Added Units (20 to 30)	-
TAGS	
Sensor Testing and System Engineering	In Progress
Engineering Model	Not before FY 1980
Production Procurement (4 to 9 Units)	FY 1985

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*Incrementally funded.

7.2 ASDE-3 DESCRIPTION

ASDE-3 will be a primary ground surveillance radar intended to replace ASDE-2 at the current ASDE-2 sites and to permit a wider deployment than is now present with ASDE-2. The unit will have the same antenna rotation rate as ASDE-2 (60 RPM) and a Display Enhancement Unit (DEU) to improve the airport map and eliminate unwanted ground clutter. The bright display will likely be the NU-BRITE display recently developed for ASDE-2. However, as an alternative to the analog scan converter used in the NU-BRITE, a digital scan conversion system will be developed for use with the ASDE-3 engineering model. ASDE-3 will be a modern solid state radar. Reliability will be high, 2500 hours MTBF in the engineering model. In addition, the system parameters will be significantly different from those of ASDE-2 in order to improve the system performance during heavy precipitation. This section will describe the functional capabilities of ASDE-3 and the relative merits of video and digital scan conversion. In addition, the physical characteristics of ASDE-3 and their impact on system performance will be discussed.

7.2.1 Functional Capabilities

7.2.1.1 ASDE-3 With the NU-BRITE - ASDE-3 will be developed to be compatible with the recently developed NU-BRITE. Except for improved rainfall performance, ASDE-3 will look (in the cab) like ASDE-2 with a DEU and the NU-BRITE. The display and controls will be as described in Section 5.2 except that where the DEU and NU-BRITE controls will not be integrated for ASDE-2, they will be for ASDE-3. Space has been made on the NU-BRITE control unit for this purpose and a sample layout is shown in Figure 7.2-1.

7.2.1.2 Video Scan Conversion (VSC) - As discussed in Section 5.2, the video scan converted bright display takes radar video, displays it on a small PPI, optically converts the PPI image to TV video with a vidicon (TV camera), and displays the TV video on a bright phosphor TV display. The vidicon is specially

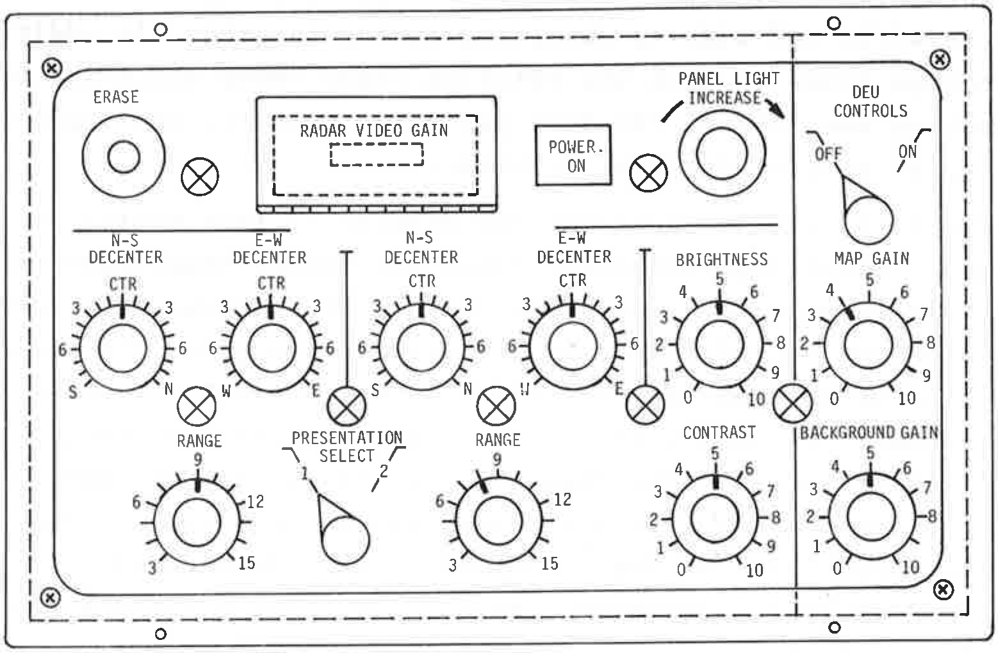


FIGURE 7.2-1. ASDE-3 CONTROL UNIT FOR VIDEO SCAN CONVERSION

designed with a slow decay silicon so that the PPI image is stored by the vidicon. The image is then written at 30 frames/second on the TV display to achieve the desired brightness.

In addition to high brightness the scan conversion process has some operational advantages. The vidicon storage maintains some target image for several radar updates (i.e. 5 or 6 updates) which results in a decaying trail on moving targets. This trail is helpful in obtaining a quick assessment of the pattern of moving traffic and aids in detecting moving targets. In addition, the storage tends to mask the rotating radar sweep which can be distracting when viewed for long periods. However, the vidicon also causes some operational problems.

The first problem concerns the display of fast moving (e.g., landing or departing) targets. Since the target image does not completely fade in one scan, slow moving targets tend to integrate the image from successive scans and get very bright. The image can get so bright that it will bloom (i.e., activate adjacent TV tube phosphor) causing a bright noisy display and poor target image. To offset this blooming the overall display brightness is turned down. A fast moving target whose image is not written over the image from the last scan will not be integrated in brightness and will, therefore, show dimly. These targets can be hard to detect.

A second problem concerns the vidicon itself. The performance of the scan converter is critically dependent on the decay rate of the vidicon. If the decay rate is too slow there is too much integration. Fast moving targets fade and the trails on slow moving targets are so long they interfere with other targets. If the decay rate is too fast the overall PPI image fades between scans. Targets are hard to detect. The antenna sweep becomes noticeable. And, target trails disappear. To date, the consistency of decay rates among vidicons, even on the same buy, has been poor. With a vidicon MTBF of 1000 hours, this results in a large degree of display performance variation.

7.2.1.3 Digital Scan Conversion (DSC) - Digital scan conversion is an alternative to video scan conversion. Rather than using a PPI and TV camera to convert the radar video to TV format and the vidicon for storage, the digital scan converter will use a digital processor. No optics or vidicon are involved. The NU-BRITE TV display would still be used. (See Section 7.2.2.)

The key advantage of the DSC is the elimination of the vidicon. The system performance would be very consistent. Storage and target decay would be under computer control. Trail length would be controller selectable. Target blooming would be eliminated. Fast moving targets and otherwise dim targets would show brightly.

The key disadvantage of the DSC is the discrete nature of the display. Figure 7.2-2 shows an artist mock-up of a small portion of a DCS display. The figure is scaled to appear as it would on a 16-inch display set with a 4500-foot range scale. The images are composed of a series of small cells and so that otherwise continuous lines can appear jagged. This cellular presentation will be evaluated in relation to its advantages via the engineering model of the DSC.

7.2.2 Physical Description

7.2.2.1 Overview - The ASDE-3 is functionally similar to the ASDE-2, eliminating several drawbacks discussed earlier. Only the features of ASDE-3 that differentiate it from ASDE-2 will be discussed.

Installation flexibility is improved by the radar performance tolerance of longer waveguide runs, and by the feasibility of dual radar installations at one site. Weather penetration is improved by the use of 16 GHz vs 24 GHz frequency band, antenna beam shaping, and the use of frequency agility. Reliability is improved through solid state electronics.

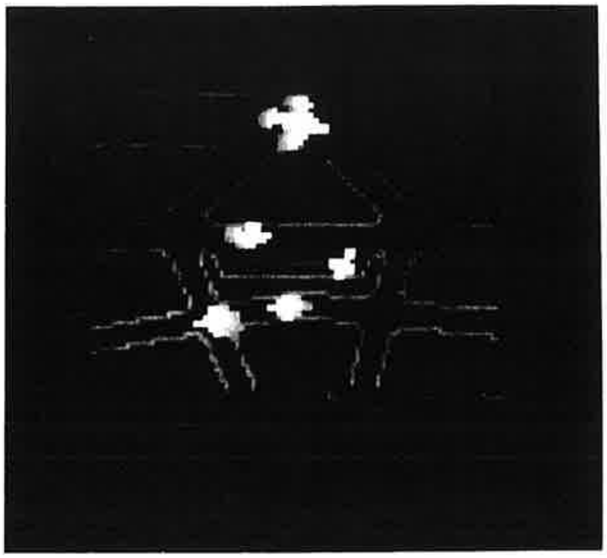


FIGURE 7.2-2. DIGITAL SCAN CONVERSION

The ASDE-3 will consist of the following elements (See Figure 7.2-3).

a. Basic radar (Antenna, Transmit/Receive, Signal Processor)

b. Display Enhancement Unit

c. Video Scan Converter

d. Digital Scan Converter (Option to be tested)

e. TV Bright display

7.2.2.2 ASDE-3 Component Descriptions - Refer to Table 7.2-1 for a list of system components and appropriate performance parameters.

a. Transmitter/Receiver

The transmitter design is considerably different from the magnetron design of ASDE-2 in that a 10 kW traveling wave tube (TWT) is used in a multi-step agile frequency mode. The relatively low transmitted power (compared with the 50 kW of ASDE-2) is offset by the ability to decorrelate and, thereby, reduce the effect of successive returns from rainfall by using several steps of transmitted frequency. Up to 13 steps will be tested with the engineering model, with nine being a likely choice.

The receiver is a frequency-agile design, matching the transmitted steps. Receiver sensitivity is considerably higher than that of the ASDE-2 primarily due to the lower frequency band (16 GHz vs 24 GHz).

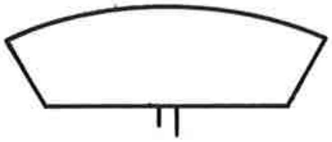
b. Signal Processing

To maintain the target received signal within the receiver linear dynamic range for all target ranges and expected rainfall conditions, an adaptive receiver gain control is used.

c. Antenna/Randome

The antenna is a horn-fed parabolic reflector enclosed within an integral rotating radome called a rotodome. The 16 foot horizontal aperture provides an azimuth beamwidth of 0.25°, equal to that of the ASDE-2. The six foot vertical aperture

TABLE 7.2-1. ASDE-3 CHARACTERISTICS

Component	Characteristic
Transmitter (frequency agile)	
Frequency	15.7-17.7 GHz (1.8 cm nominal)
Pulse width	36 ns (6dB point) Trapezoid
PRF	20 kHz
Peak Power	10 kW traveling wave tube
# frequency stops	9 steps of 15 MHz each. (30 MHz will also be tested)
Antenna	
Reflector Size	17 ft horiz., 63 in vertical
Horizontal Beamwidth	0.25° at half power points
Vertical Beamwidth	1.6° at half power points, CSC shaping
Tilt	+ 1°, -1.5°
Polarization	circular
Scan Rate	60 rpm
Radome	Integral Rotodome* 18' diameter
Rooftop Weight	1400 lb design goal
Receiver	
Noise Figure	6 dB
Bandwidth	38 MHz
Gain Control	Adaptive STC
Display System Video Processing	
DEU	solid state, synthetic map interface with receiver
DSC	solid state scan conversion
TV BRITE	standard FAA NU-BRITE
	

*Surface of revolution

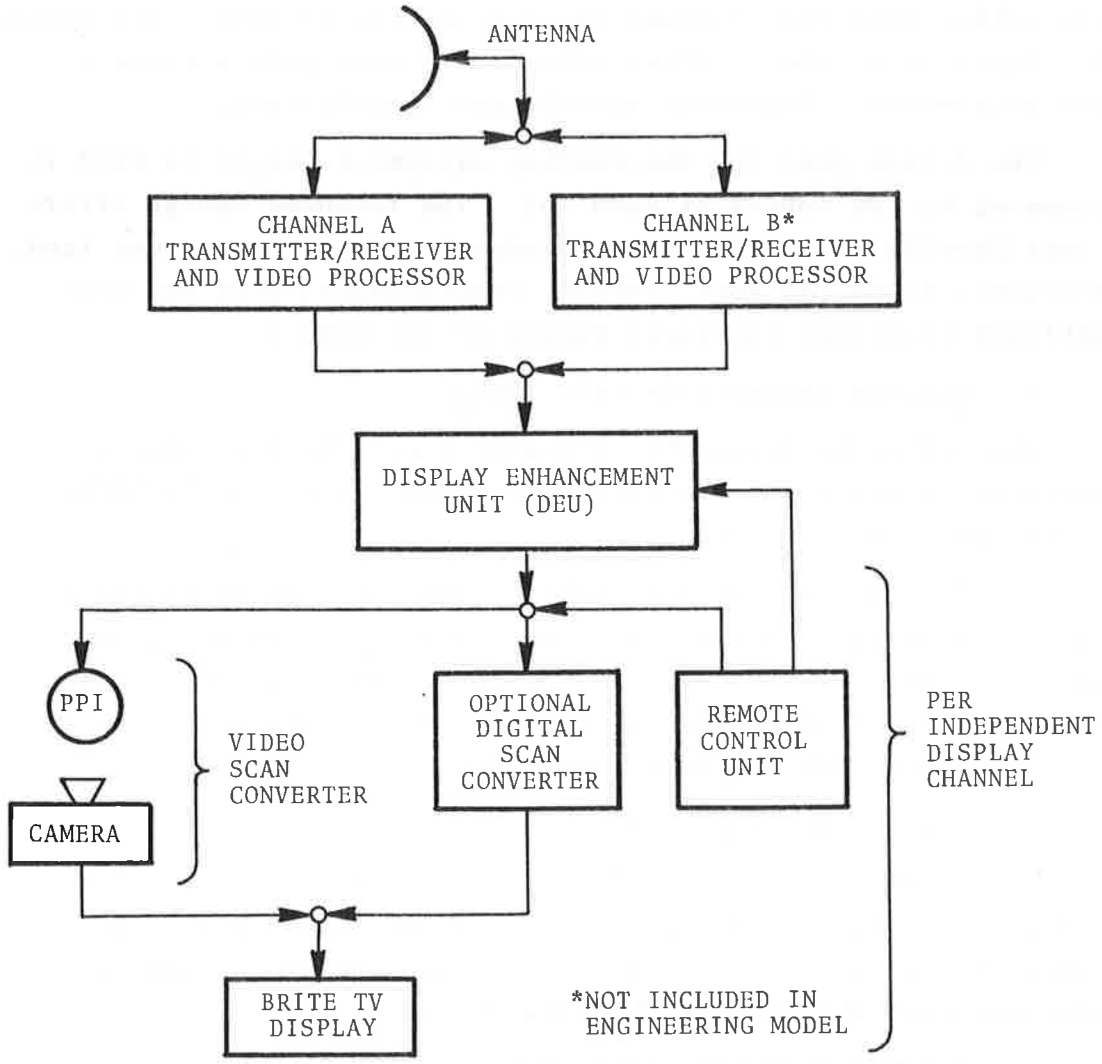


FIGURE 7.2-3. ASDE-3 BLOCK DIAGRAM

provides vertical beam sharpness equivalent to the ASDE-2 (1° between the half power points), but is shaped in a cosecant pattern rather than the cosecant squared pattern of ASDE-2 optimizing the signal-to-weather clutter ratio. Circular polarization is used to provide a degree of rainclutter cancellation.

The design goal for the rooftop equipment weight is 1400 lb (compared to the ASDE-2 of 2500 lb). The rotodome design offers a considerable reduction in wind-induced overturning moment (and, therefore, tower cab roof strength requirements) over the conventional truncated spherical radome of the ASDE-2.

d. Display Enhancement Unit (DEU)

The DEU to be delivered with ASDE-3 will be functionally identical to the digital implementation described in the ASDE-2 discussion. (See Section 5.2.)

In addition to providing gated video for display purposes, the DEU is integrated into the ASDE-3 design, providing gated video for internal ASDE-3 functions. For example, video from isolated airport surface areas is required for the adaptive receive gain design mentioned earlier.

e. Video Scan Converter

The optically coupled video scan converter system is the NU-BRITE described in the ASDE-2 Section of this report (see Section 5.2). The ASDE-3 video output and control signals will interface with the current NU-BRITE design.

f. Digital Scan Converter (DSC)

The digital alternative to the optically coupled vidicon/PPI design uses a computer memory to provide the interface between the asychronous R-θ radar position information and the TV raster line format. The major benefits of the digital design are in the improved reliability (vidicon is eliminated), ease of adjustment (critical display nonlinearities in the PPI/vidicon are eliminated), and its stability (solid state electronics).

The major functions within the DSC are:

- polar to Cartesian coordinate conversion
- 2 samples per range cell on every sweep increment for critical area video
- D/A conversion of sampled video
- Multiple sweep, running-sum integration
- Sampled video stored in memory in 8 shades of gray
- Digital video decay (operator selectable time constant)
- Data readout in TV line format for display

Signal processing in the DSC is essentially limited to the integration of multiple target hits from a single antenna scan of a target. The display threshold is selectable to provide the tradeoff between false alarm rate and target detection to be varied.

The access time of the solid state memory ultimately limits the number of range samples that can be taken from a single radar sweep for a particular range interval. For currently available memories of reasonable access time and storage size, 512 cells per radar range can be accommodated. At 18 ft/cell, 512 cells results in a minimum range for full memory utilization of 9000 ft. This level of resolution can be selected by offset to encompass any chosen 9000 ft. radius airport area. Display magnification and offset are used to appropriately fill the operational display scan.

DEU map line video is mixed internally in the DSC and input to the DSC memory, becoming indistinguishable from target and background video in memory. Map lines and stationary targets are continually updated in memory to their current amplitude, preventing the decay function from operating on them. Only moving targets are decayed.

The DSC interfaces with the high resolution 1225-line NU-BRITE TV display unit.

7.2.2.3 System Performance Characteristics

a. Resolution/Target Definition

The transmit pulse width/receive bandwidth combine to give a theoretical range resolution of about 20 ft., essentially equal to the ASDE-2 performance. The 0.25° azimuth beamwidth gives 40 ft. of azimuth resolution at 6000 ft. range. Antenna aziumuth movement per pulse repetition interval is less than 2 feet. Although the basic resolution and image definition performance of ASDE-3 should be equivalent to a well-maintained ASDE-2, the frequency-agile operation should improve the consistency of target cross section by reducing fluctuation effects.

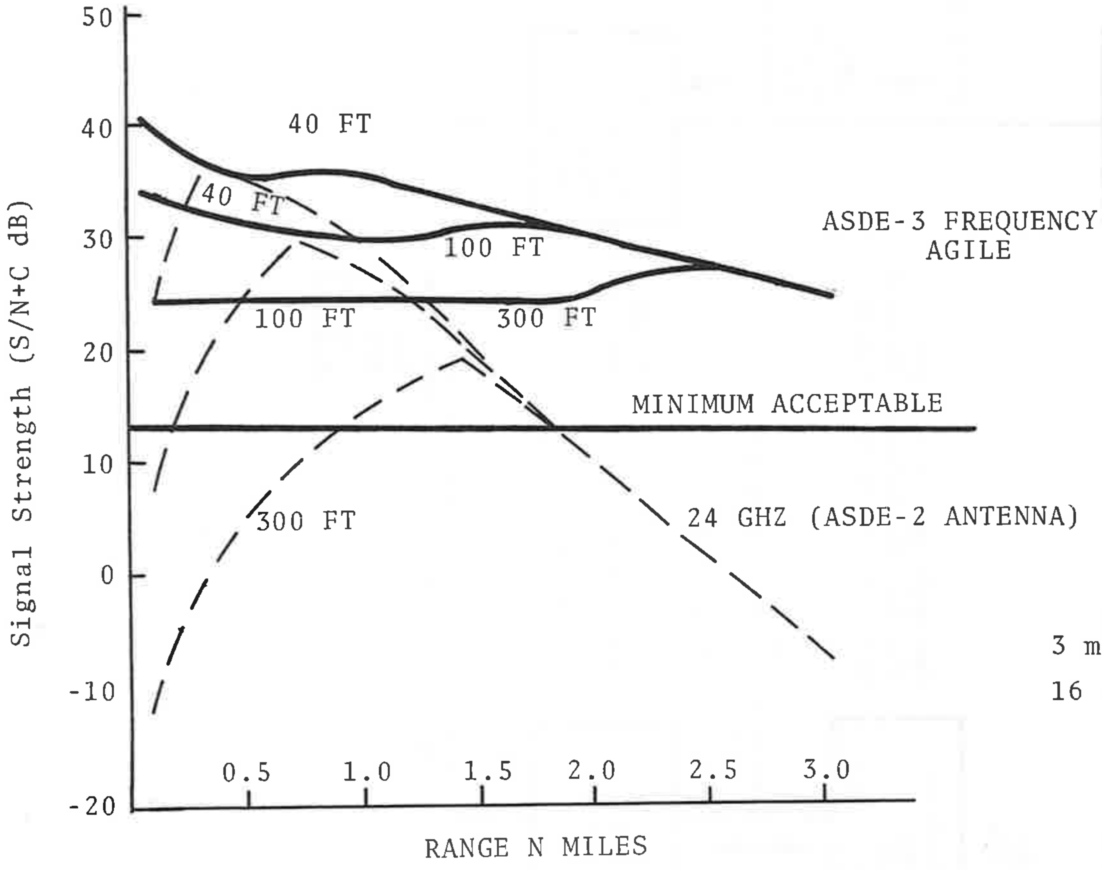
b. Weather Penetration

The combined effect of the lower frequency band, reshaped antenna and frequency-agile operation result in considerably improved performance in precipitation (See Figure 7.2-4). The plot shows predicted performance in heavy rainfall for three tower heights. The horizontal line represents the minimum acceptable signal to noise ratio for reliable detection of a small target. The ASDE-3 provides considerable performance margin at all ranges. Of particular importance is the elimination of close range "white out" experienced by ASDE-2 due to precipitation backscatter. An ASDE-2 mounted on a 200-foot tower can experience close range clutter limited performance in rainfall rates as low as 4 mm/hr!

c. Installation Flexibility

The ASDE-3 offers a variety of installation features not available with the ASDE-2 - (Refer to Figure 7.2-5).

100-foot waveguide run, allowing the transmitter receiver group to be below the tower cab



3 m^2 Target
16 mm/hr rainfall

FIGURE 7.2-4. ASDE-3 PERFORMANCE IN HEAVY RAINFALL

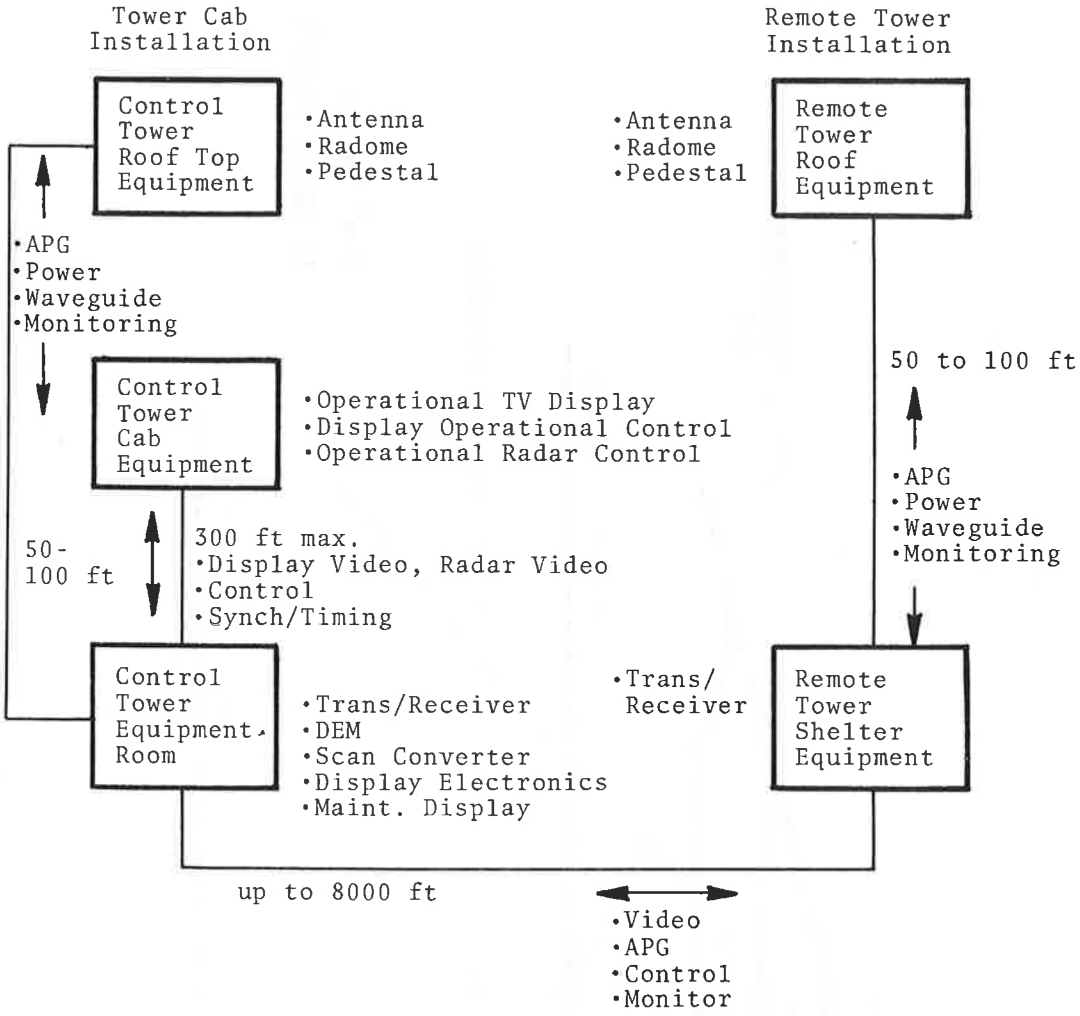


FIGURE 7.2-5. ASDE-3 INSTALLATION CONFIGURATIONS-SINGLE RADAR SYSTEM

Lighter weight, lower wind drag rotodome for installation on tower cabs which could not withstand ASDE-2 rooftop equipment.

Adaptation to allow tower heights from 40 to 300 feet

Dual radar operation to provide coverage of large airports where one ASDE installation would have blind spots

Remote siting of antenna and transmitter/receiver up to 800 feet from the tower cab

7.2.3 System Integration

ASDE-3 integration with other UG3RD elements, with the exception of TAGS, has not been considered. ASDE-3 integration/installation into the current cabs has only been considered to the extent that:

1. The installation is flexible. It can be mounted in the console, on a table top, or hung from overhead. The control unit is separate (remote) from the display, adding flexibility.
2. The NU-BRITE can be used in a 945 line mode and so can be used to display ASR/ARTS BRITE presentations. Thus, it serves as a back-up to these systems.

Actual installation is left entirely to the receiving facility.

7.2.4 Failure Modes

Figure 7.2-3 shows a block diagram of the ASDE-3. In the operational system (not the engineering model) the transmitter/receiver section and video processing will be redundant with an A and B channel. Therefore, electronic failure in one of these channels will not result in an ASDE failure. As currently planned the DEU will not be redundant. However, DEU failure will not cause overall system failure. The primary radar with the map generated with ground clutter will still be available. Each independent display channel will be single channel except that more than one BRITE TV display may be used. Therefore, failure of the scan converter, except for the TV display, will result in system loss when only one display channel is installed. Of course, multiple display channels would provide redundancy in addition to presentation flexibility.

If ASDE-3 sustains a system failure, the operational back-up is pilot position reports via voice channel. This mode would force operation at a reduced traffic level but in low volume situations has proven quite safe.

7.3 TAGS DESCRIPTION

ASDE-3 will provide the cab with a plan view display of the Airport Movement Area (AMA) and the location of surface traffic on the AMA. The purpose of TAGS is to add flight identity information to such a plan view display. The objective is to eliminate the need for the controllers to use the voice channel to obtain flight identity as is now done with ASDE-2. The chief user of TAGS will be Ground Control although it will also be provided to Local Control.

Several TAGS concepts are currently under consideration for development. This section briefly describes the alternatives and then describes in some detail the alternative most likely to be chosen. The rationale for selecting the most likely alternative is also given.

7.3.1 Alternative TAGS Concepts

Th first two system alternatives involve the means of sensing the identity and position of the aircraft. One sensor alternative (digitized ASDE-3) is to perform digital target detection and declaration on ASDE-3 radar video in order to provide target coordinates to a digital processor. The processor would then track the target and provide filtered position and velocity information. For arrivals, ARTS would provide aircraft position, course, ground speed, and flight identity. With this information the arrival runway and estimated time of arrival would be established by TAGS and used to automatically associate identity with each target as its track is initiated on the runway. For all other targets the initial association of identity and position would be entered manually by the controller. Once the association was made it would be maintained by the tracker.

The second sensor alternative is to use the existing ATCRBS beacon on board each aircraft to provide position and beacon code. TAGS is only expected to be installed at Group I TCA airports and so each aircraft will be beacon equipped. The TAGS sensor, in this case called ATCRBS trilateration, does not use the beacon in a secondary radar mode but in a special ground surveillance mode. Special interrogators would successively scan small (150 foot by 150 foot) cells on the airport movement area, one at a time. The beacon signals would be received at multiple receiver stations and the beacon location determined by trilateration computations. Beacon code would also be received and recorded. (The sensor technique is described in detail in Section 7.3.4). As with digitized radar the position data would be processed by a filter tracker to provide smoothed position and velocity. Unlike digitized radar, beacon code would also be available. Automatic correlation with flight plan data readily obtained from ARTS would eliminate the need for nearly all manual entry by the controller.

The second two system alternatives involve the method of presenting the position and identity information. One presentation alternative is to simply add the target identity information to the ASDE-3 (with DEU) display with data blocks and leaders as is done by ARTS-3. A mock-up of such a presentation at O'Hare is shown in Figure 7.3-1. The mock-up utilized the engineering model of the NU-BRITE display system. As can be seen, the identity tags not only provide identity but can improve target detectability.

A second presentation alternative is to use the smoothed position information to provide a fully synthetic plan view display. No primary radar would be displayed. A raster type

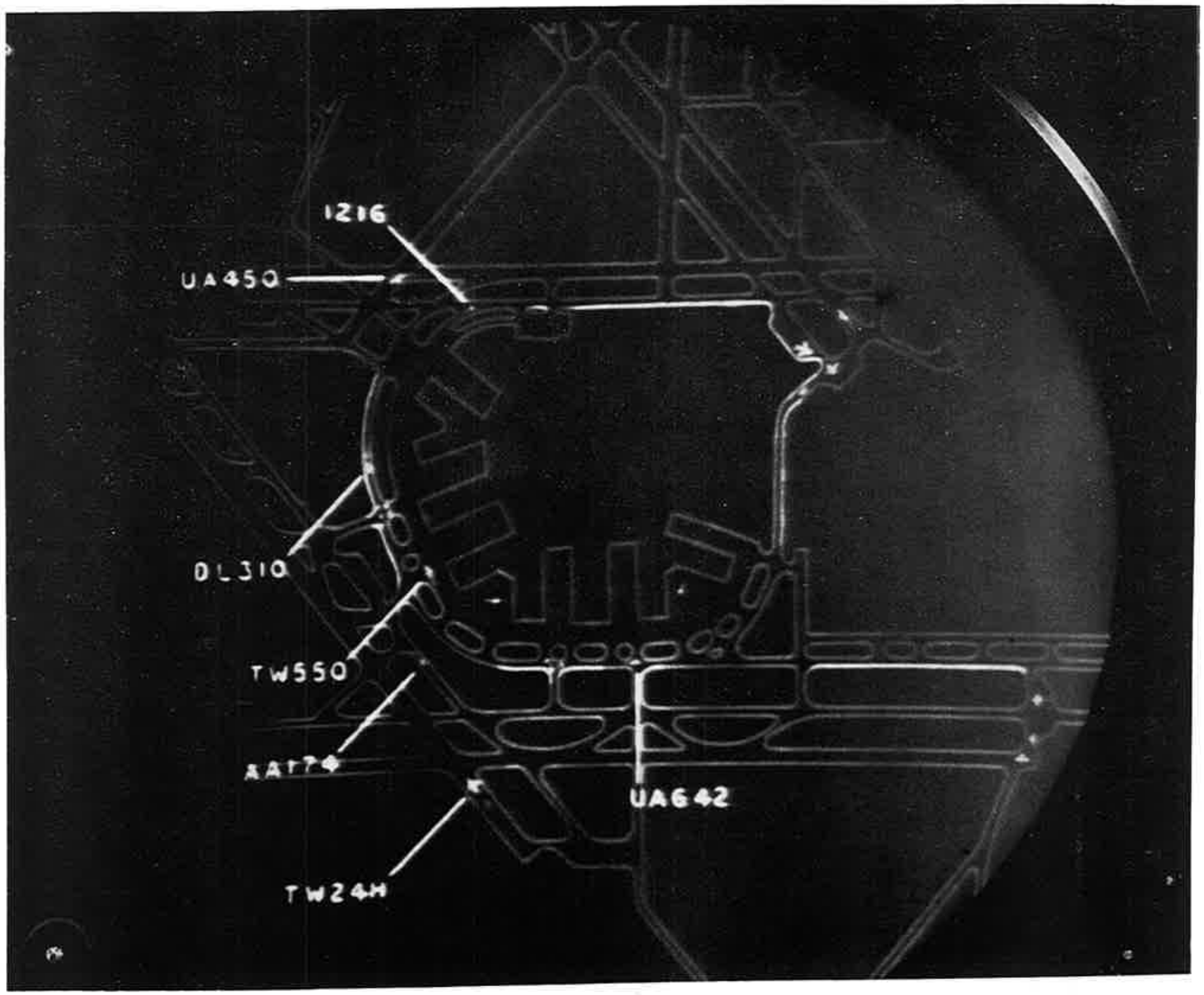


FIGURE 7.3-1. TAGS DISPLAY BASED ON ASDE-3 PPI

display would not be required and an X-Y addressable stroke type display could be used to improve the crispness of targets and alphanumerics. A photograph of such a display taken from a TAGS format simulation is shown in Figure 7.3-2. The airport is Chicago O'Hare.

7.3.2 Hybrid TAGS System Concept

The most likely to be developed TAGS concept is one with its presentation based upon ASDE-3 (with DEU) and its identity information provided by ATCRBS trilateration. Therefore, to the controller, TAGS will likely look like Figure 7.3-1. The system will require two different surveillance systems, ASDE-3 to present a plan view display and ATCRBS trilateration to provide identity and aircraft location to permit tagging each radar target. Since the system will combine both sensor systems it is termed a hybrid system. This section provides the rationale for selecting the hybrid system as the most likely to be developed TAGS concept.

The advantages of the hybrid system over other system alternatives are as follows:

1. The ASDE-3 targets provide aircraft size and shape information (termed target extent). Extent is important in establishing runway and taxiway intersection clearance especially of aircraft holding short. In some instances a pilot holding near a runway (e.g., having just crossed a runway to enter a departure queue)will have a difficult time assessing the clearance of the aircraft's tail. It is unlikely that a full synthetic display based either on digitized radar or ATCRBS trilateration would be able to display extent as accurately as primary radar and more reliance would have to be placed on the pilot with regard to critical area clearance.

   Extent information can also be used to detect aircraft turning at very slow speeds. While filtering the position information from digitized radar or ATCRBS

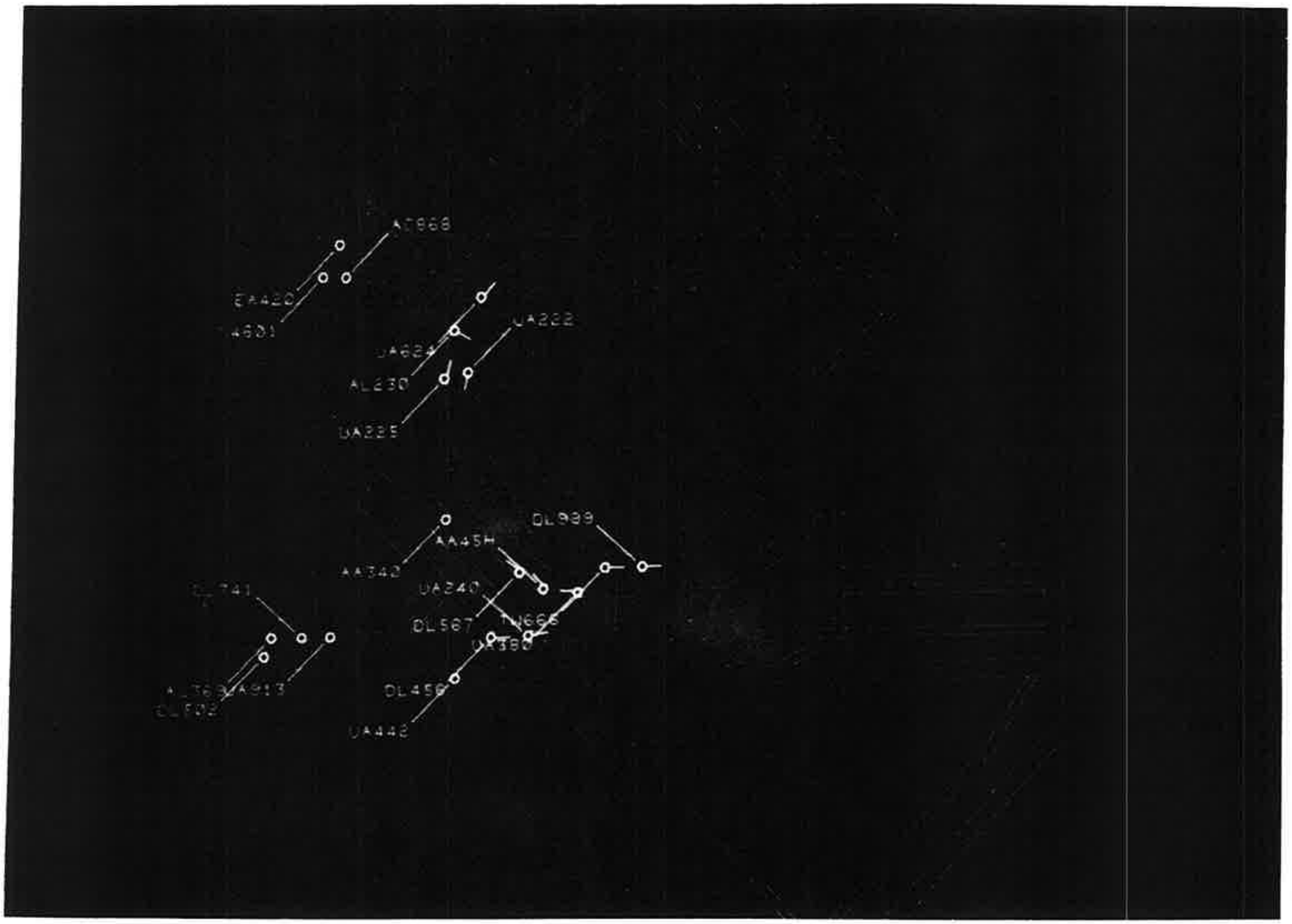


FIGURE 7.3-2. FULLY SYNTHETIC TAGS DISPLAY

trilateration will provide course information, this would likely be available only when the aircraft was moving above a threshold speed of say 10 knots.[1] Aircraft, particularly wide-bodied aircraft , can slow below that threshold speed when exiting a runway at 90 degrees or reverse turn exits and turning information can be very useful in anticipating runway clearance of the aircraft. It can also be useful in detecting an incorrect turn at a taxiway intersection in time to alert the pilot to take corrective action.

2. The hybrid system provides optimum target coverage. The primary radar will detect all surface targets except in very heavy rainfall, whereas a system based only on ATCRBS trilateration would only detect beacon equipped targets. While some service vehicles which often travel on the Airport Movement Area (AMA) could be equipped with a cheap beacon, it would not be practical to equip all service vehicles with beacons which operate on the airport surface (including the service roads). Unequipped vehicles lost in fog and on an active runway would go undetected by ATCRBS trilateration. Even a system based only on digitized radar would likely compromise target presentation since it might miss small targets which a controller could visually detect on the PPI, especially in heavy rainfall conditions.

   While the primary radar target presentation is satisfactory in fog, in heavy rainfall it will tend to lose targets (as would digitized radar). However, ATCRBS will detect all equipped vehicles in all weather conditions. In the event ASDE is obscured due to heavy rain, ATCRBS will permit presentation of at least all the aircraft moving on the AMA.

3. The hybrid system provides optimum airport surface coverage. ASDE is often centrally located on the tower cab. If not, it is located on the opposite side of

the airport from the cab (and terminal/ramp area). In either case it generally has fairly good ramp coverage. ATCRBS trilateration will not have good ramp coverage. It will not look down behind satellite terminals (as ASDE does in Los Angeles) or between terminal fingers (as ASDE does at Chicago O'Hare). This coverage is very useful in permiting ramp advisories where only one way traffic flow is permitted.

However, because it is single sited , ASDE can have blind spots in certain local areas (e.g., behind large satellite buildings, or terminal facilities such as hotels, power stations, etc.). ATCRBS trilateration is a multi-receiver sensor and will provide full coverage of the taxiways and runways including any ASDE blind spots that might exist.

4. The ATCRBS-based method for deriving identity requires little or no controller inputs. Beacon code is continuously provided for each target. IFR filed aircraft have beacon code and identity correlation available from ARTS. VFR arrivals in the TCA are normally entered in the TRACON and so their beacon code and identity correlation is also available from ARTS. VFR departures in the TCA are normally entered in the cab and so their beacon code and identity correlation is available. Only those few VFR aircraft not entered will not automatically be provided flight identity. These will be displayed as beacon code and can be manually entered by ground control if so desired. In addition if a track is dropped due to a temporary lack of data, the ATCRBS based sensor will automatically reinitiate track since the beacon code is available when data sensing is resumed.

With digitized ASDE a more involved hand-off of arrival information from ARTS is required and target and identity correlation on all targets but arrivals must be manually entered by the controller. This workload could be higher than that associated with mentally (with aid of pilot position reports) retaining the identity of untagged targets. Manual input would also be required if tracks were dropped or swapped (between aircraft which move close together such as at a taxiway intersection).

5. Using primary radar for position permits a larger error budget for tracking accuracy. If an all-synthetic display is used, movement detection would place fairly severe requirements on sensor and processor.[3,4] This accuracy is not required if the primary requirement for position is simply to locate the identity tag.
6. The hybrid approach provides two dissimilar sensors resulting in improved system reliability. If the trilateration sensor-processor should fail, only identity would be lost. The most critical information (i.e, aircraft location, especially with regard to the runways) would still be available. If the ASDE-3 should fail, position and identity would be available on all aircraft. While the target information would not be of the quality provided by ASDE, the resulting display would be far superior to no display at all (the current result of an ASDE failure).

The disadvantages of the hybrid system over other alternatives are as follows:

1. The only proven technology for displaying a bright ASDE radar plan view is a raster based TV display. The NUBRITE display now available uses a "sticky" vidicon as a storage medium with which to rapidly refresh a bright phosphor TV display. The vidicon optically converts the ASDE PPI image into TV video. If, as is now done with the ARTS BRITE, the alphanumeric tags are also optically converted to TV video, there will be a significant loss in alphanumeric readability over those drawn on an X-Y addressable stroke type display. To compensate for the loss, the alphanumerics must be fairly large

(for high legibility 0.22 inches high on a 14.5 inch display with 1000 raster lines). Even at this size the alphanumerics at some A/N BRITE facilities are somewhat "fuzzy" due to transmission loss from long cable runs.

These large alphanumerics can cause display problems on an ASDE display. Surface targets are not uniformly spread out on an ASDE PPI as they normally are on final approach on an A/N BRITE. They can become quite densely packed. The resulting identity tags will tend to overlap each other and the targets compromising identity readability and, more importantly, target detection. Automatic tag offset switching, as is available for ARTS, can aid in reducing the overlap problem but the switching itself is distracting to the controller. As a result it is often not used on ARTS. In addition, in recent TAGS simulation tests performed at Chicago O'hare, 14 of 18 controllers tested found ARTS type automatic switching unacceptable and recommended consideration of smaller alphanumerics. It is possible that digital scan conversion of the identity tags can permit smaller and more legible alphanumerics (see Section 7.3.4.4). However, to date this approach has not been studied in detail.

2. The hybrid system described above will likely be the most expensive alternative. However, an alternative means of interrogation for the trilateration sensor is being investigated and will be tested during upcoming sensor tests at Boston Logan airport.[5] If feasible, it could reduce the hybrid system costs.

7.3.3 Hybrid Functional Capabilities

The only published TAGS operational system description is for an ATCRBS trilateration based system with a fully synthetic display.[6] No hybrid system definition work has been done to date. This section is, therefore, preliminary in nature and not complete. It has been prepared for use in initial MSDP integration studies. The description is based upon TAGS as described in Reference 6 and the current alphanumeric BRITE system.[7, 8] The system departs from Reference 6 in the following key respects:

1. The system is hybrid using ATCRBS trilateration to provide target beacon code. This change follows the rationale in the previous section. In addition, a field survey was made of five major airport towers (Boston, New York-JFK, Atlanta, Los Angeles and San Francisco) in which case TAGS system alternatives were described via slides and comments solicited from FAA tower and region personnel. Of the five airports, three suggested the hybrid during a synthetic system description and two (Los Angeles and San Francisco) would not give up primary radar (ASDE) for an all synthetic TAGS.

2. Data blocks are one line only containing flight identity (or beacon code) and a single alphanumeric modifier for weight class. The second line of flight data described in Reference 6 is omitted. Flight data is assumed to be provided by flight progress strips or their replacement, TIPS. This change is the result of a TAGS display alternatives simulation which was filmed and taken to Chicago O'Hare for evaluation by eighteen controllers. In the evaluation a format depicting a combined arrival and departure ground control display (i.e., all arrivals and departures shown with identity) with one line data blocks was shown. Alphanumerics were 3/16 inch in height, on the small side for a raster presentation, and despite this the display was considered unacceptable by 72 percent of the controllers due to the cluttering effect of the data blocks. Individual displays for arrival and departure ground control were acceptable (to 72 percent of the controllers) but two-line data blocks would have doubled the alphanumeric clutter (as did the combination of arrival and departure ground control) and would likely have been unacceptable as well.

3. Each control position will be provided with its own independent display and display controls. Up to six independent channels will be available (e.g., to permit three Ground and three Local Control positions as is occasionally the case at Atlanta). Combined displays will be available as a system option (e.g., for use by one ground controller handling both arrivals and departures when traffic is light) but it is unlikely that they will be shared by two ground controllers. When there is enough traffic to justify two controllers it is unlikely that it can all be tagged legibly (see item 2 above).

4. Only traffic within the confines of the airport is considered. In Reference 6 a Local Control display which integrates information on airborne arrivals (on final approach) and airborne departures (prior to hand-off from Local Control to Departure Control) with the TAGS was considered. That integrated display concept was presented during the TAGS field survey and was not favorably received. Tower personnel preferred the scales, etc. associated with the ARTS BRITE display and did not wish to compromise either the surface or airborne display through integration. The integrated concept is described in Section 7.3.5.2 to aid in future integration considerations.

7.3.3.1 Tower Cab Equipment - The display used by the hybrid system will be the NU-BRITE display described in Section 5.2. The NU-BRITE/DEU control unit will be functionally the same as that described in Section 7.2 except that the components will be new to provide digital signals (e.g. range and offset) to the TAGS processor. A TAGS alphanumeric (A/N) control panel will then be added to the NU-BRITE controls in much the same way that the ARTS A/N control panel is added to the ASR BRITE controls. The combined unit is shown in Figure 7.3-3. The TAGS A/N panel would

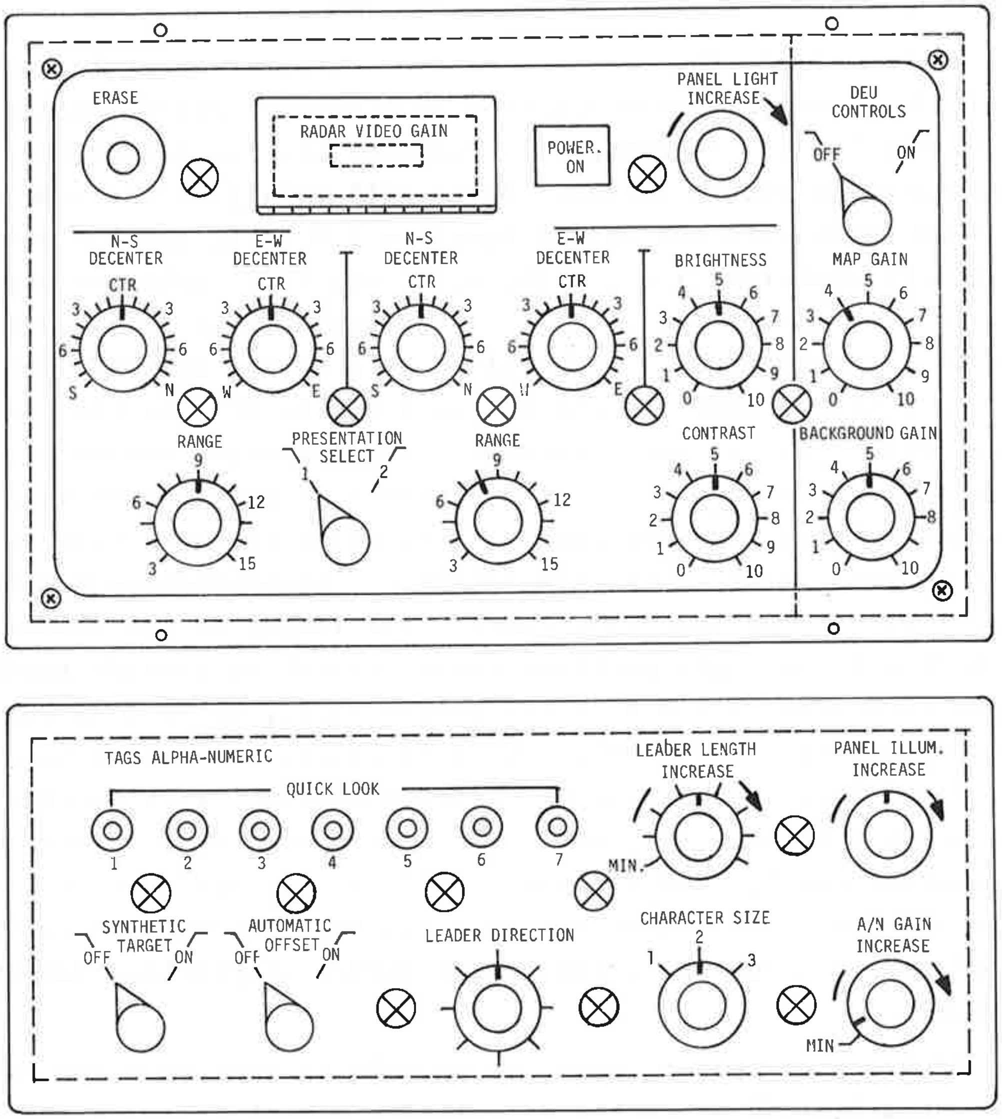


FIGURE 7.3-3. COMBINED TAGS HYBRID CONTROL PANEL

be the same size as the ARTS A/N panel, 12.7 inches wide by 5 inches deep. The combined panel would measure approximately 12.75 inches wide by 14 inches deep by 3.25 inches high.

Both units in the combined control panel are back lighted with panel illumination controlled by a push-to-turn potentiometer. See Figure 7.3-3.. Alphanumeric character size is controlled by a three position rotary switch. Sizes will likely be the same as on the ARTS BRITE with the height equal to 1.0, 1.5, and 2.0 percent of the CRT diameter (i.e., 0.16, 0.24, and 0.32 inches respectively on a 16 inch diameter display). Alphanumeric gain (i.e., brightness of alphanumerics) is controlled by a rotary switch. Setting this gain with respect to the map gain of the DEU and the radar target brightness is very critical. Alphanumerics should be set between the other two items in brightness to permit reading alphanumerics written over map lines and to allow the detection of radar targets lying under alphanumerics. Alphanumerics and the leaders are of the same brightness. The length of the leaders is controlled by an eight position rotary switch to provide leader length from zero to 1/8 of a CRT radius (i.e., up to 2 inches on a 16 inch diameter display). The data blocks can either be offset in a fixed direction or can be switched automatically to reduce data block overlap. The option is selectable from a switch on the control panel. The automated logic is described in Section 7.3.3.4. The fixed offset option needs the direction of offset specified. An eight position rotary switch is provided for this function.

If for some reason, such as an ASDE failure or heavy rainfall obscuring ASDE targets, a synthetic target (e.g., a small computer-generated box) is desired, a switch will be provided on the control panel to select such targets. At this point it should be noted that while the rotation rate of the ASDE-3 and the update rate of the trilateration based targets (and identity) are planned to be the same (i.e., once per second) they may not be synchronized. In this case, synthetic targets (and data blocks) will not necessarily advance at the same time the primary radar target does. For this reason it is likely that synthetic targets would only be selected when primary targets were not present.

The last switches on the control panel are a set of seven spring loaded toggle switches for "quick-look". If the controller desires to display an alternative display format, the appropriate switch would be held down and the new format would be displayed until the switch was released. The formats are discussed in Section 7.3.3.6.

The TAGS A/N control panel is intended to contain all frequently used display controls. However, to set up the display and provide flexible data entry, a keyboard and position entry module (PEM) will be required. The units will be of similar construction as the corresponding units for the ARTS BRITE (See Section 5.1), however, some of the functions (function buttons) will be altered for application to TAGS. Some of the necessary functions are described in the following sections.

7.3.3.2 ATCRBS Trilateration Sensor/Processor Controls - The ATCRBS trilateration system is based upon the successive interrogation of small geographic cells on the Airport Movement Area (AMA) to obtain single beacon replies for position and code extraction. One way in which to interrogate each target would be to enter a map of the entire AMA (by magnetic tape or cards) and interrogate all cells lying within the AMA for each target reply required. However, for adequate filtering, target data is needed about four times per second. There can be literally thousands of cells within the AMA of a large airport (2000 estimated for Chicago O'Hare) resulting in too high an interrogation rate to be feasible.[4] (1520 interrogations/sec. is considered an upper bound.[10]) The solution to be used is as follows:

1. Use the filter tracker on each tracked target to provide a small set of cells in the neighborhood of each target for rapid (4 interrogations per second) interrogation.

2. Through use of the keyboard and PEM, enter geographic coordinates for areas in which targets commonly originate. For each area an addressable name will be defined (e.g., RAMPS for airline ramp area, BUTLR for general aviation apron). These areas will be scanned at a moderately fast rate (1 interrogation/second) for automatic track initiation except that not all runways (on which arrivals originate) need be interrogated continuously. Based upon an automatic data transfer from ARTS of position, velocity, course, beacon code and identity, the arrival runway (or runways if the runway cannot be uniquely determined) and time-of-arrival for each arrival will be determined. Then at the appropriate time and on the appropriate runway, a cell scan will be made for automatic acquisition.

3. To automatically acquire targets entering the AMA or other than the defined geographic areas and to automatically reacquire targets whose track for some reason is lost, the entire AMA will be interrogated but at a slow rate (every 15 seconds). This will permit the total interrogation rate to stay within the prescribed upper bound.

4. If for some reason auto-acquisition as described above is not adequate (e.g., the target lies outside the defined acquisition areas and the slow scan is too slow to suit the controller or a target is located off the AMA outside the slow scan, such as, a service vehicle on the grass wanting to cross a runway), the track may be manually initiated using the keyboard entry and PEM. For all types of acquisition the method and, where available, the geographic area of acquisition will be stored in the newly created track file for later use.

5. If a target track is lost due to an interruption in data flow the filter will coast the target location for three to five seconds and then hold its position until the target is automatically reacquired. Once in

the coast mode a large hexagon will be drawn at the estimated location (regardless of the synthetic target selection) to cue the controller of the problem. If the controller sees the associated radar target he can manually reacquire track via the keyboard and PEM. If the aircraft has already reached the ramps and turned off its beacon prior to automatic reacquisition, the controller can manually drop track via the keyboard and PEM. Of course, the controller may drop track on any target at any time but the pilot will have to be directed to turn off his beacon or the target will be automatically reacquired.

6. When a target which is being tracked reaches its destination and turns off its beacon it will appear as a lost track. To prevent this, tracks will not be treated as lost tracks when their track is lost in certain geographic areas. In general, these areas will correspond to previously defined auto-acquisition areas (e.g., the airline ramps, general aviation apron). As aircraft enter these areas they will either become blocked from the receiver sites or will turn off their beacon at which time track will automatically be dropped. If these areas are well defined, very little manual track dropping will be required.

7.3.3.3 Display of Data Blocks - A critical problem for TAGS i to display identity on targets for which it is required and only on those targets for which it is required. This is to keep at a minimum the display cluttering effect of identity tags which can compromise identity legibility and more importantly, target detection and traffic flow pattern recognition. The following section describes several means for classifying targets. Each class would be defined with an associated name (e.g., ARVLS for arrivals). Target sets composed of these classes of target could then be selected from the keyboard to have their flight identity displayed (or in some cases suppressed). The classification means are as follows:

1. Targets can be classified by the area and/or means of track initiation which will be stored in the track file at the time of acquisition. For example, if Ground Control is divided into two positions, one for arrivals and the other for departures, Arrival Ground Control can configure his display to display identity of all targets acquired on the runways by way of an ARTS data transfer. To those targets would be added all targets manually acquired from the keyboard/PEM associated with the Arrival Ground Control's display. Departure Ground Control could elect to display only aircraft acquired in (leaving) the airline ramp area omitting other departures to reduce identity related clutter. However, to those aircraft could be added aircraft acquired in the general aviation and cargo areas, and all targets manually acquired from his keyboard/PEM.
2. Targets can be classified based upon flight plan data available from ARTS. This data would identify IFR arrivals and departures and, since TAGS would be at a Group I TCA, most VFR arrivals are normally entered in the TRACON. VFR departures are either entered from the cab (by flight data position) or special beacon codes are reserved for VFR departures but are not entered. In either case, the departure is identified as such. This classification would provide an alternative to that in item 1 when Ground Control was divided between arrivals and departures.
3. Targets can be identified by their beacon code (for display or identity). In this manner, emergency codes (e.g., 7700 and 7600) could be identified on all displays. Also, each control position could be assigned a unique code (e.g., code 4020 for Arrival Ground Control) for assignment to surface vehicles such as towed vehicles,

gate to hanger taxis, and airport service vehicles. All targets with the code associated with a particular position could then be displayed on that controller's display. This would eliminate the need to manually enter the identity on such targets.

4. Special geographic areas can be defined for controlling the display of identity. These areas would be set up and associated with a name by use of the keyboard and PEM. The area names would then be used to configure the controller's display. Examples of such areas and their use are as follows:

   (a) If Local Control is divided into two positions with each controller controlling a geographically distinct set of runways, each set of runways and their adjacent taxiways can be geographically defined. Similarly, if Ground Control is geographically divided (e.g., east-side and west-side as at Atlanta); each side can be geographically defined. In this manner, each controller may select identity tags solely on his traffic.

   (b) Since it is very difficult to provide identity tags when many targets are in close proximity, areas such as departure queues and holding pads can be defined and identity tags suppressed while the targets are located within them. For some positions several areas would be suppressed and these areas might be dependent on the runway configuration in operation. In this case during runway configuration changes several keyboard entries might be required to reconfigure the display. To avoid this it will be possible to define sets of such geographic areas by name for association with particular runway configurations.

5. Targets can be manually identified for display of identity (or identity suppression) by use of the PEM and/or the keyboard.

7.3.3.4 Display of Leaders and Data Block Offset - The identity data blocks are offset from the targets and associated with the targets by a leader. The leader length is selected from the A/N control panel. In addition, if the fixed offset option is selected, the direction of offset is specified from the A/N control panel. However, in the fixed offset mode, the direction of offset may be overridden from the keyboard for the various classes of target associated with the display of identity. For example, if arrivals and departures were to be displayed together on a single display, their data block offsets could be prescribed to lie in opposite directions to identify each class and better spread out the data blocks of closely spaced targets. Also, if the airport were geographically divided in a natural way (e.g., Los Angeles with north-side and south-side operations divided by the terminal area), targets in each area could be offset in the favorable direction for that area (e.g., at Los Angeles north-side targets offset to the north, south-side to the south).

The alternative to fixed offsets is the automatic offset option. However, the automatic logic used here is not the same as the logic used by ARTS. The ARTS automatic offset option is frequently turned off due to the distraction caused by frequent switching. In addition, in simulation testing of TAGS display formats done at Chicago O'Hare, the ARTS data block logic was found unacceptable by 78 percent of the controllers tested. The automatic offset logic being proposed for use by TAGS employs a slow switching technique to reduce the amount of switching. In the traffic scenario simulated at O'Hare (2 minutes in duration) a 70 percent reduction in switching (over ARTS logic) was obtained and the format was found acceptable by 44 percent of the controllers. In the slow switching concept only aircraft traveling in tandem which have overlapped data blocks for a prolonged period (i.e., over 15 seconds) are switched to prevent overlap. With this logic some short term overlap (often only partial overlap) is permitted in order to reduce the distraction associated with frequent switching.

If the fixed offset option is selected and if the leader is selected to be very short it may not be necessary to actually display the leader since the data block is close enough to the target to make correlation possible without a leader. In this case, the leader can be deleted from the keyboard. Leader length on the A/N control panel will then refer to distance of offset for the data block.

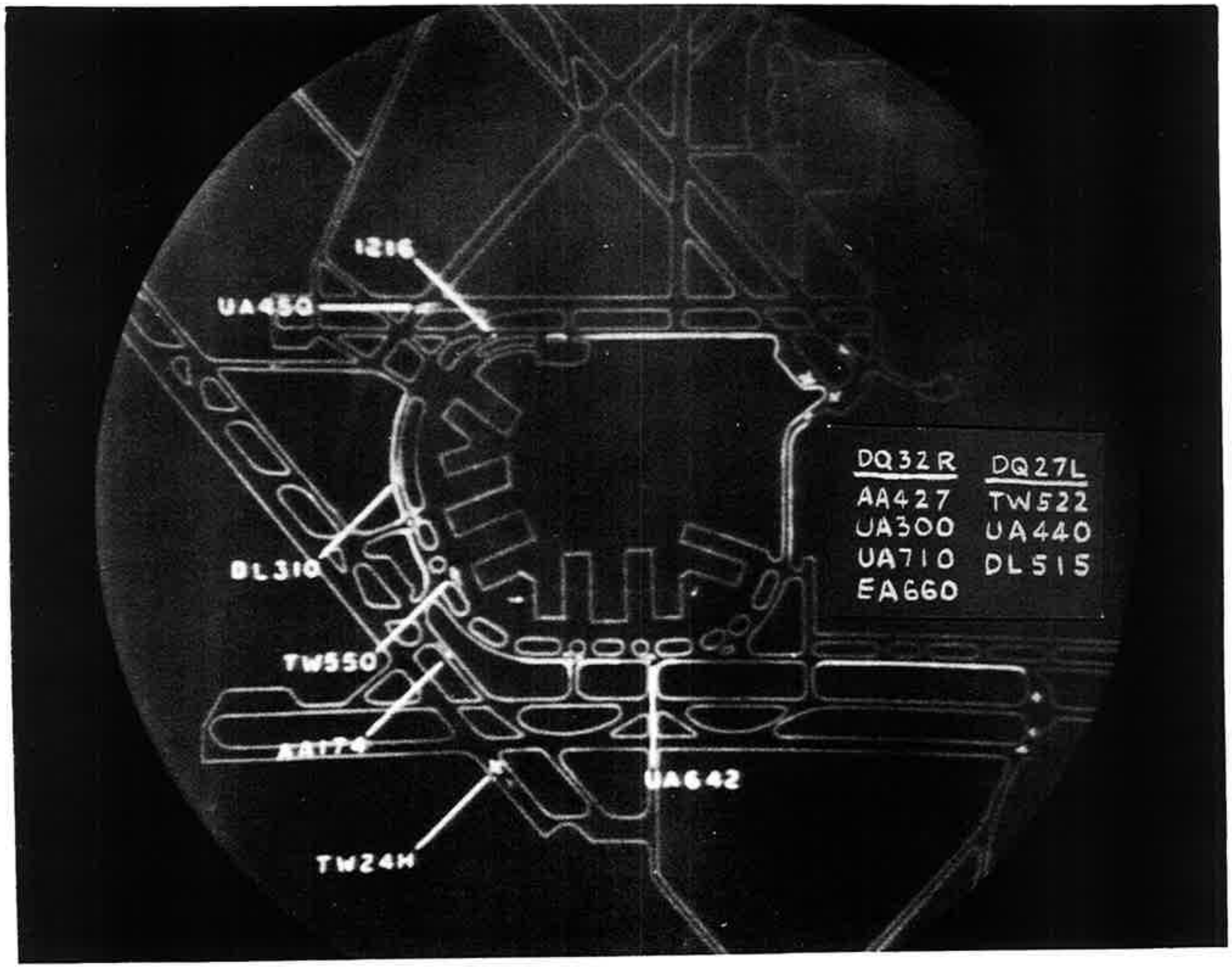
7.3.3.5 Tabular List Display - If it is desired to keep track of which aircraft are associated with various classes of target, a tabular list of the identity of those targets can be called up by the controller. The location of and space for the list will be specified by the controller via the PEM and keyboard. Location of the list will be important since to get the best target extent information possible the range scale will be set to fill the display with the area of interest. The controller will not want the list to interfere with the airport map and targets over which it will write. In addition, since data blocks will not be written in the list area, those that would lie there will be blanked.

Examples of classes which could be useful in a list are departure queues for Departure Ground Control and Local Control especially if data blocks are suppressed, and aircraft in holding pads awaiting a gate. The list area will be filled from top to bottom and left to right. For each class specified a sublist will be made with the class name as a header (e.g., 32RDQ for the 32 right departure queue, PENBX for the penalty box holding area). Field size for each sublist will be specified as input from the keyboard when the list option is selected. For each sublist (target class) the aircraft identity will be added to the bottom of the list as it joins the class (e.g., enters the geographic area). As it leaves the class the identity will be removed and the list regrouped to fill the gap which would otherwise be left.

An example of a tabular list is added to a hybrid display mock-up in Figure 7.3-4. Alphanumerics are 0.25 inches high to match data block alphanumerics for high legibility. It can be seen that while only two sublists are selected and very few aircraft are in each queue, the list takes up a substantial portion of the display. If the queues were longer (and adequate field size were specified) the lists would run over the runway and departure queue. This figure illustrates the limitations of the tabular list and the care with which the list will have to be used.

7.3.3.6 Quick-Look Option - TAGS will provide up to six independent display channels for use in the cab. At any one display the controller will be able to display the identity of targets which are tagged on any of the other five displays by depressing the quick-look switch associated with that display. Six switches are reserved for this purpose to permit the same assignment of switches (to displays) at each station. This will avoid confusion as the controllers rotate positions within the cab. When the switch is depressed the identity blocks will be applied to those targets tagged on the associated display, however, the format will be that associated with the requesting control panel (i.e., range, offset, alphanumeric size, etc. will not change).

The seventh quick-look switch is reserved for the controller to configure as he chooses from the keyboard (and PEM). For example, Arrival Ground Control may set up the quick-look to see all ground traffic (except for departure queues and holding areas) identified. South-side Local Control might choose to see all runway related traffic on both sides of the airport identified.



DQ32R	DQ27L
AA427	TW522
UA300	UA440
UA710	DL515
EA660	

FIGURE 7.3-4. HYBRID DISPLAY WITH TABULAR LIST

7.3.3.7 Supervisory Controls - The shift supervisor will have access to a TAGS keyboard for supervisory control of the system. Functions will include position consolidation to permit a simple way of showing on one display the identity of targets being tagged on more than one display. An example of its use would be to display identity of both arrivals and departures when traffic is light (e.g., in late evening or early morning) and only one ground controller is used. Also included is a hardware configuration function. This function would permit associating any control device (A/N control panel, keyboard or PEM) with any display. Its principal use would be in the event of control device failure.

7.3.4 Physical Description

7.3.4.1 Overview - The hybrid TAGS system comprises three major subsystems as follows. Refer to Figure 7.3-5.

a. The Sensor Subsystem consists of two independent surveillance systems, the ASDE-3 and the ATCRBS-based multilateration Data Acquisition Subsystem (DAS). The sensor provides the data acquisition function, including target declaration, position computation, and beacon code extraction information, and control of the multilateration interrogation process. The ASDE to multilateration sensor registration function is minimized by not attempting to correlate by computer the independently obtained target information.

b. The Processor Subsystem provides track acquisition and track management, ATCRBS Mode 3/A code to flight identity correlation, external system interfaces (ARTS) and inputs to the display subsystem.

c. The Display Subsystem presents the processed track information from the ATCRBS multilateration system merged with the unprocessed (non-synthetic) ASDE-3

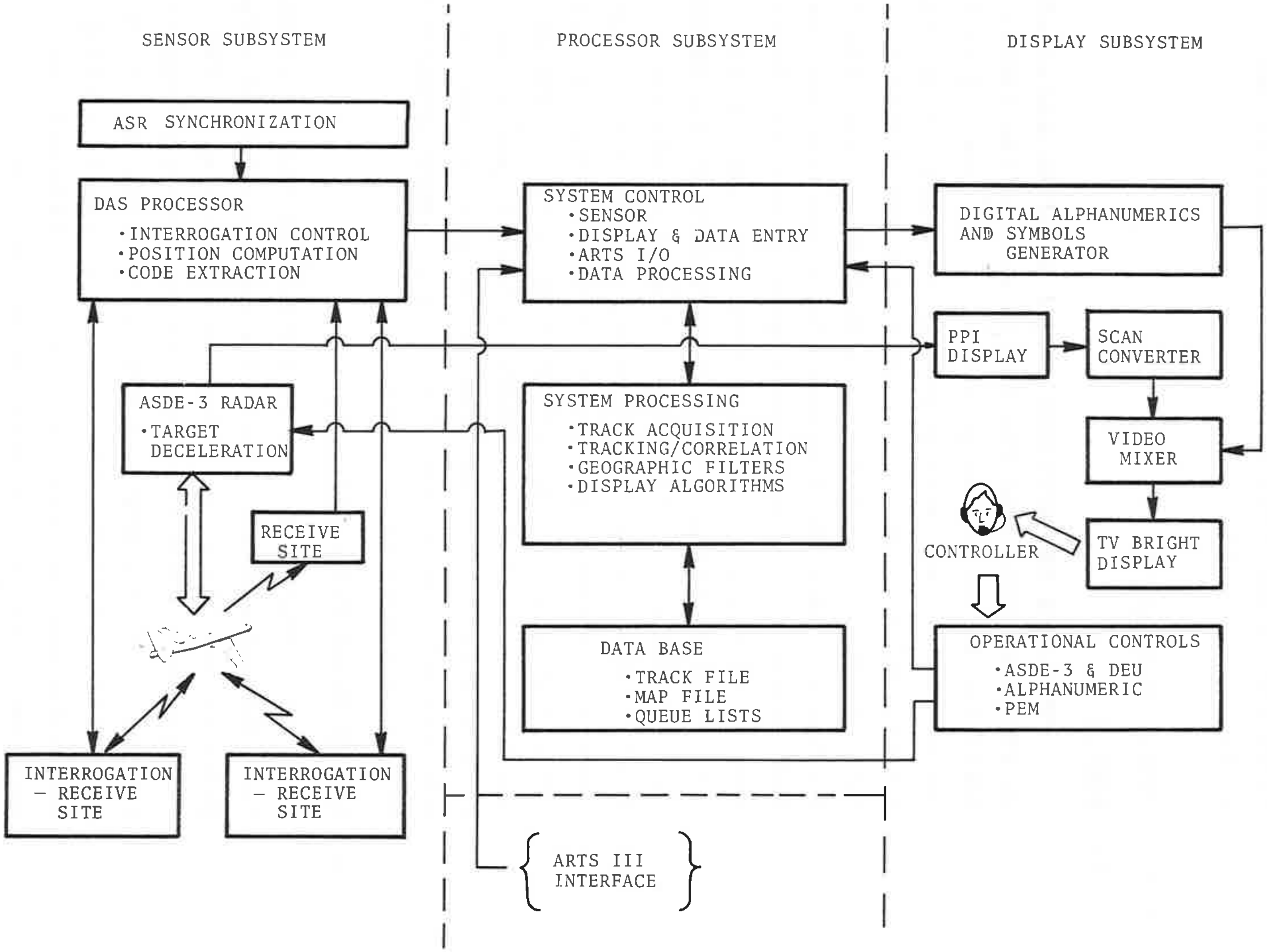


FIGURE 7.3-5. TAGS HYBRID BLOCK DIAGRAM

target information. The display function includes alphanumeric and symbol generation techniques and operator data entry.

7.3.4.2 Sensor Description

1. ASDE-3

Providing the accurate target position and extent information feature of the hybrid system, the ASDE-3 is identical to the system described in Section 7.2 with the exception that timing and control information (range, offset, and TV synch) compatible with the multilateration system is required. As with ASDE-3 alone, the TV display provides the dominant timing function for the TAGS hybrid due to the asynchronous natures of the TV raster system, the ρ-θ radar sweep and scan and the interrogation search and track operation of the ATCRBS multilateration system. The ASDE will retain the Display Enhancement Unit, providing radar critical area video and synthetic map lines. Either method of scan conversion can be used (see Section 7.2), digital or analog. No tracking or synthetic target generation will be done. The scan-converted display output is unprocessed video except for sweep-to-sweep integration and input signal thresholding.

2. ATCRBS Based Multilateration

The primary function of the hybrid TAGS is to provide the correlation between the surface-located target position and its flight identity. Requiring ATCRBS transponder equipped targets, the beacon-based multilateration system provides the sensor input to accomplish this function. The sensor uses electronically scanned monopulse (sum-difference) pattern antennas, overlapping two transponder suppression patterns radiated from two separate sites to leave a region of interrogation about 100 feet by 100 feet called a "cell." Refer to Figure 7.3.6. Transponder replies from a target within the cell thus isolated must be received by, at least three sites (called a triad in the minimum configuration). Position is calculated from time-of-arrival measurements using hyperbolic multilateration techniques. Transponder 4096 reply code information is extracted and validated by multiple receiver site comparisons. Pertinent performance details of the multilateration system are:

a. Coverage (Refer to Figure 7.3-7)

The interrogation baseline distance for a single triad is limited to about 9000 feet due to system timing constraints. An ideal triad requires ±30° scanning by the electronically steerable arrays, readily achieveable without sacrificing beamshape and pointing accuracy. To maintain accuracy and resolution, the cell should be as near rectangular as possible, within a boundary inside the triangular area within the triad. To achieve coverage of all airport critical areas in a large airport, several triads will be necessary (9 sites for Chicago, for example). Complete coverage of gate areas and other areas where shadowing precludes their visibility may not be economically feasible.

ARTS ASR-based coverage and TAGS coverages will not overlap at most airports. The discontinuity may be handled by using last known position and velocity information on an automated data transfer from ARTS to develop estimated time of arrival in order to begin a search mode for arrival acquisition.

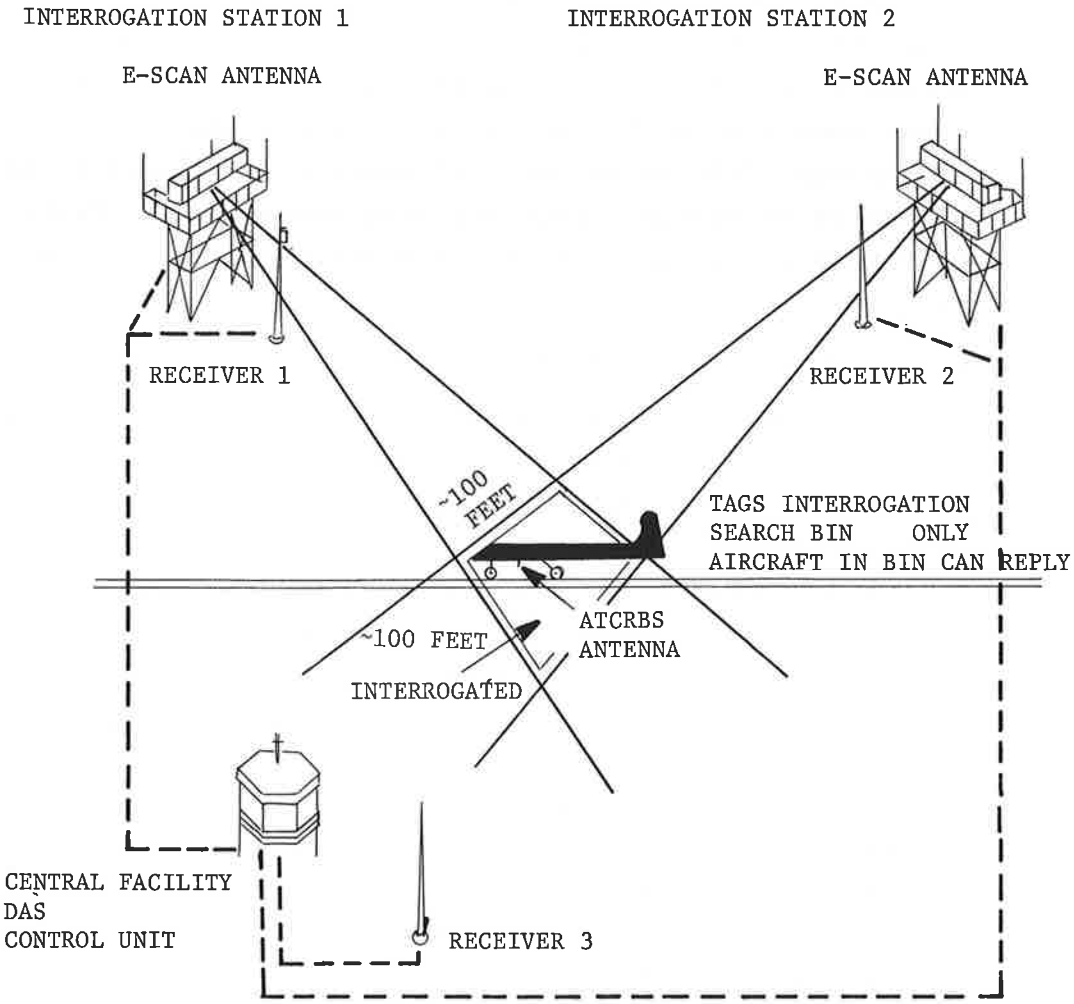


FIGURE 7.3-6. INTERROGATION AND REPLY PROCESS

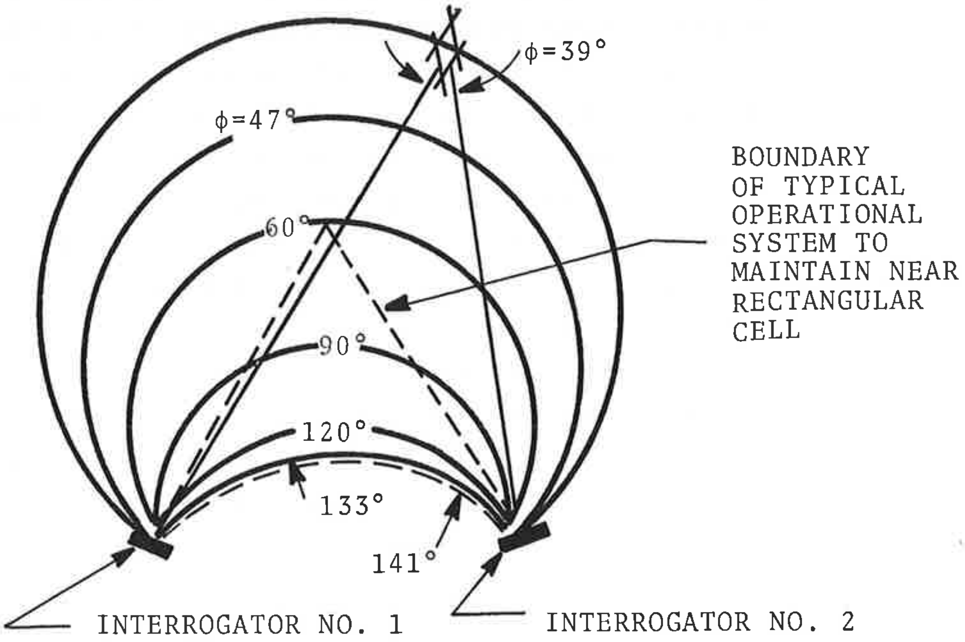


FIGURE 7.3-7. INTERROGATOR COVERAGE ZONES

b. Resolution

Successful operation of the system depends on its ability to discriminate between closely spaced aircraft. Resolution capabilities are determined by the effective antenna interrogation (suppression) beamwidth. This beamwidth, in turn, is a function of the electronically scanned antenna azimuth pattern shape, the relative levels of the transmitted ATCRBS pulses, and the suppression/reply characteristics of the individual transponders. Because the U.S. National Standard for ATCRBS allows some latitude in the relative pulse amplitudes for 1 percent to 90 percent reply probability, the multilateration system must cope with this uncontrolled variation. As depicted in Figure 7.3-8, the contours for reply probability from 1 percent to 95 percent for a beam intersection angle of 90° indicate that the resolution cell size will vary from 225 feet to 75 feet. To prevent variation of cell size as a function of range along the spatially diverging antenna null, the transmitted pulses are controlled to maintain the nominal cell size at 100 feet, and no less than 50 to 75 feet.

c. Accuracy

Although accuracy is a function of target location within the triad, one sigma x-y position error is less than 20 feet (Figure 7.3-9). Tracking accuracy will be discussed in the processor subsystem section.

d. Target Capacity and Update Rate

The multilateration system operates in the dead time of the ASR (Airport Surveillance Radar), limiting it to about 1500 μ seconds per beacon repetition period. One-hundred twenty-five

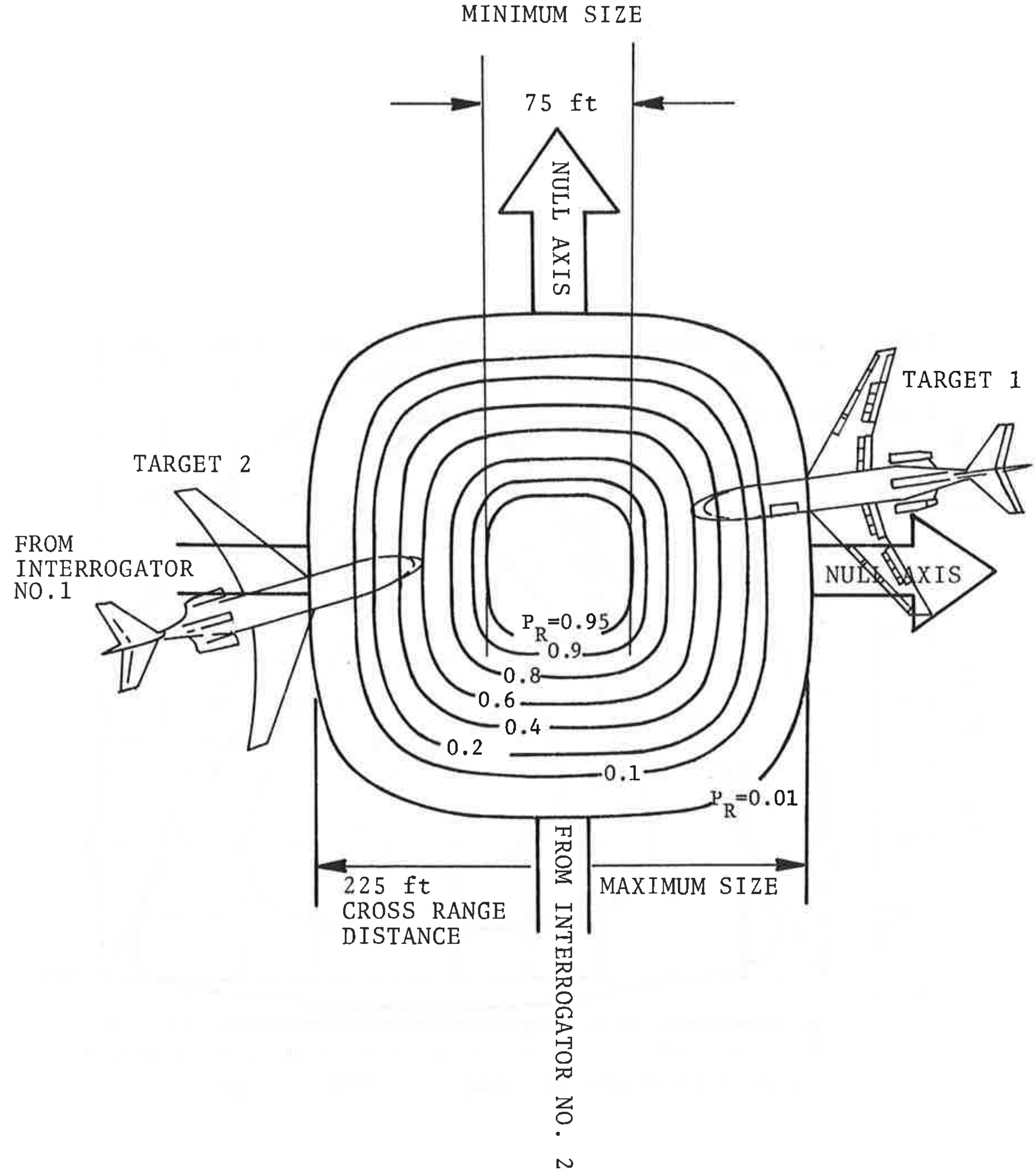


FIGURE 7.3-8. CELL COVERAGE OF TWO CLOSE PROXIMITY AIRCRAFT

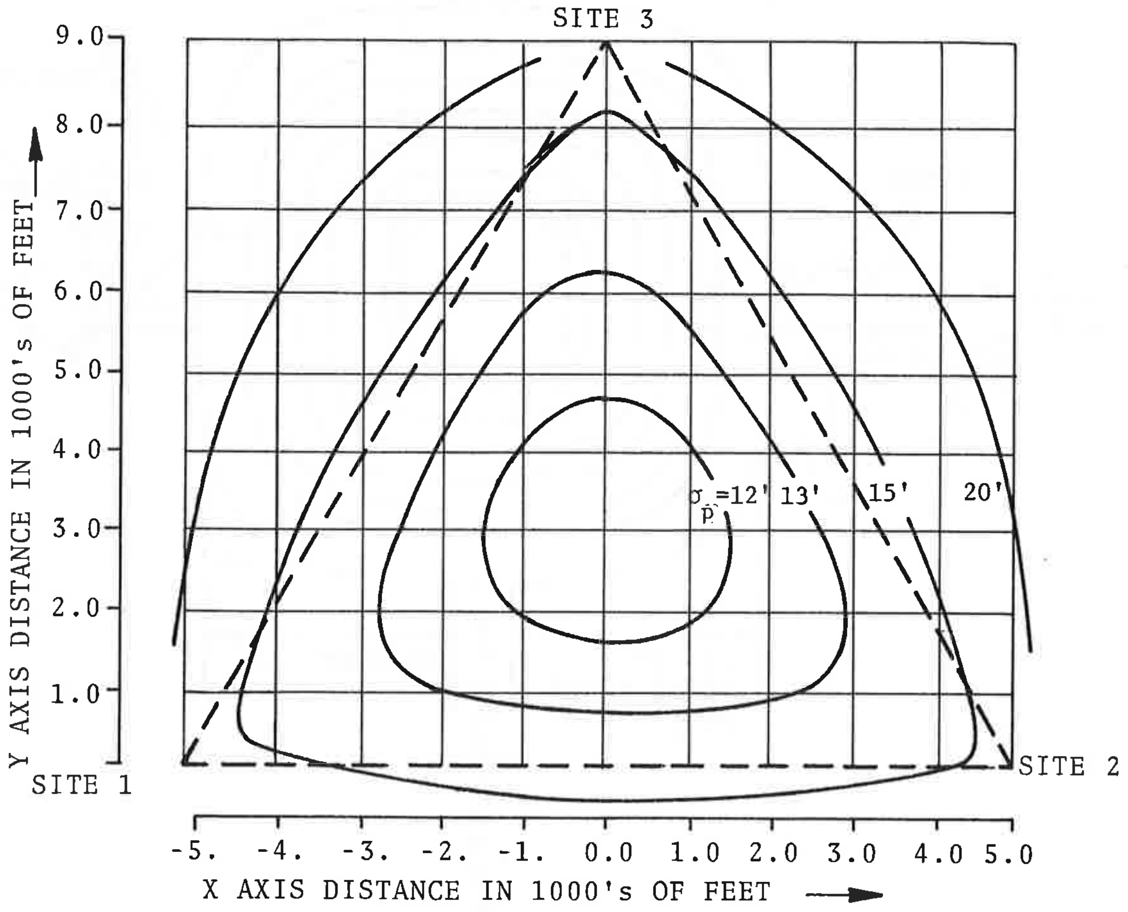


FIGURE 7.3-9. SINGLE TRIAD TRILATERATION ACCURACY CONTOURS ESTIMATED FOR A TWO-MILE BASELINE TRILATERATION SYSTEM

μ seconds are allocated for each multilateration interrogation cycle or "time slot". Thus a total of 12 time slots per beacon period can be used. At an ASR beacon pulse repetition rate of 400 per second, a total of 4800 time slots per second forms the upper limit for the multilateration data rate. A worst case analysis has shown however, that the maximum interrogation rate required to handle all targets at the busiest airport (O'Hare) is under 1500 per second for the all-synthetic TAGS sensor. In light of the goal to minimize interference to the airside ATCRBS environment, the maximum interrogation rate is interference-limited rather than system-saturation limited. Table 7.3-1 shows how the total interrogation rate is shared among all of the various tasks involved in acquiring and maintaining target tracks at the four airports most likely to receive TAGS. The rates shown represent the most reasonable interrogation rate requirements associated with the hybrid system, where a degradation in turn rate detection and position measurement accuracy can be tolerated. Note that in every instance except Chicago, the multilateration interrogation requirements can be met with two time slots per ASR Beacon dead time interval. Chicago rates would have to be reduced by very little to also use two slots per dead time for a nominal beacon pulse repetition frequency of 400 Hz.

d. Control of Data Acquisition Process

The intelligent portion of the sensor subsystem is referred to hereafter as the data acquisition subsystem (DAS) control. DAS control is responsible for managing the process of:

Target declaration and sending x-y position reports and correlated ATCRBS codes to the processor for use by the tracker

TABLE 7.3-1. TAGS ATCRBS INTERROGATION RATES

BASIC INTERROGATION RATE		Major TAGS Airports							
		Chicago		Altanta		Los Angeles		Kennedy	
		# Targets	Inter. Rate	# Targets	Inter. Rate	# Targets	Inter. Rate	# Targets	Inter. Rate
Towing or Taxing Aircraft	@ 2 inter/sec	60	120	44	88	35	70	33	66
Non-Aircraft on Taxi/Runways	@ 2 inter/sec	10	20	10	20	10	20	10	20
Aircraft on Runways (Local)	@ 4 inter/sec	15	60	10	40	10	40	10	40
Aircraft in Departure Queues	@ 1 inter/sec	15	15	10	10	10	10	25	25
Reinterrogation Rate (Basic Rate X 35% X 5/sec)			376		277		245		365
Auto Acquisition	@ 1 inter/sec	100	100	75	75	133	133	159	159
Background Search (All Areas in 15 sec)			134		64		75		117
Total Interrogations Per Second			825		574		593		691

Target quality indicator sent to processor

New target indication sent to processor

Reinterrogation search for lost or poor quality targets

Degarbling

Lost target (if search fails) indication to processor

Limited position prediction for the next interrogation

Interrogation cell size

DAS control also receives, interprets and acts on commands from the processor subsystem as follows:

Cease interrogation of particular targets (drop track)

Search/auto acquisition, both slow (15 seconds) and fast (1 second) in regions defined by the processor subsystem

Update rates required for each target

Smoothed x-y position prediction at track update rates as computed by the processor tracker

Manual target acquisition commands.

No detailed tradeoffs between placement of the above functions in the processing subsystem instead of the DAS control have been studied. The type of hardware implementation has not been determined.

The above functions fall into two broad categories:

1. Target Declaration and
2. Interrogation Control

DAS Target Declaration

TAGS target reports are generated within the sensor subsystem and sent to the processor subsystem for track update and other ASTC functions. Upon receipt of an interrogation, a transponder within a cell emits its discrete 4096 mode 3/A ATCRBS reply. Each multilateration receiver determines the time-of-arrival (leading edge of first reply train bracket pulse) and digitizes the ATCRBS code, sending the information to DAS control with an indication of garble. Degarbling is done at the receiving site. To assist the receiver in detection, a priori knowledge of expected code, which has been range-gated will be provided from the DAS control report file. DAS control uses the replies from the multilateration receivers to calculate target position and to formulate a target message from the correlated beacon codes. A target quality indicator is added to the message, reflecting the degree of certainty, depending upon the number of receiving sites reporting no-garble 3/A codes. New potential tracks not currently in the processor track file can be flagged, and lost targets (following unsuccessful reinterrogation) can be reported to the processor subsystem.

DAS Interrogator Control

Logic with DAS control is provided to control the antenna pointing angles, transmitted pulse power levels, and timing of suppression and interrogating transmissions. The logic accomplishes the maintenance of uniform interrogation cell size regardless of location on the airport surface by varying effective interrogation beamwidth. DAS control logic provides a simple x-y position prediction using information from the target report file to keep the cell approximately centered around the target as it moves. To assist in the prediction, processor-derived, track-position predictions are provided at the processor track update rate (slower than actual interrogation rate). DAS control exercises search procedures (area wide, or selected area) for new target acquisition within geographic areas bounded by processor subsystem commands. Processor search area commands translate airport areas into antenna beam pointing angle limits.

The processor subsystem instructs the DAS control as to the required interrogation rate for each target in the report file. When the DAS logic fails to generate a target report on a given interrogation time slot, it automatically initiates a reinterrogation procedure in an attempt to satisfy input requirements for the processor tracking function. The DAS is responsive to processor drop-track actions by ceasing interrogation of the particular target. Operator input track acquisition commands via the processor are also carried out by the DAS to search the requested area.

7.3.4.3 Processor Subsystem - The primary task of the hybrid TAGS is to place a flight identity tag, displayed adjacent to its associated ASDE target, and to maintain the association throughout target track life. This function must be accomplished with a minimum of operator actions, requiring automatic target and tracking initiation for arrival and departure aircraft and autoreacquisition for tracks coasted or dropped due to loss in sensor data. The TAGS processing subsystem to meet the above requirements is primarily concerned with:

1. ARTS interface (Flight data and track data transfer)
2. Correlation of sensor reported target x-y position/Mode 3/A identity with flight identity
3. Output of information for symbol and alphanumeric display to associate with ASDE targets
4. Management of sensor data acquisition to maintain data rate, and to respond to operator inputs.

The major functions of the Processor-Subsystem are discussed below.

a. Sensor Subsystem Interface

The processor exercises sensor control by communication with DAS control. Interrogation rates for each tracked target, coordinates of search areas derived from operator inputs (or ARTS interface), predicted target position (based on tracker output), and target status (drop-track or active) are sent to the DAS. Target report messages, including quality and status (lost or new target) are received from the DAS by the processor.

b. ARTS Interface

Three types of communications are required by TAGS via the ARTS interface.

1. Flight data
2. ARTS III tracker last reported position and velocity.
3. Departure handoff

Flight data in the form of aircraft flight identity, discrete beacon code assignments, and an indication of heavy or non-heavy are obtained through ARTS regardless of whether such data is "canned" or manually input via the ARTS system. The ARTS III tracker-reported position and velocity (and, of course, correlated flight identity and beacon code) are obtained for approaching flights to allow the TAGS processor to compute estimated time and runway of arrival to initiate auto-acquisition search. Departure handoff will accomplish the inverse of the auto-acquisition function by providing ARTS with a solid indication of departure.

c. Data Processing and Data Base Maintenance

The most important processing task is the tracking/correlation function. Sensor-reported beacon codes and x-y position are correlated with existing data residing in the track file. The track file (Table 7.3-2) will contain the flight identity versus beacon code as well as position status and estimated movement information.

TABLE 7.3-2. TRACK FILE[12]

For each target in TAGS system:	
1. Beacon Code	ARTS or DAS interrogation
2. Aircraft Identity	ARTS
3. Heavy-Light Indicator	ARTS
4. Arrival-Departure Indicator	Track Correlation Function
5. X-Y Location	ARTS or DABS integration
6. Target Quality Indicator	ARTS or DAS integration
7. Target Status - New or Lost	DAS integration
8. Estimated X-Y Location	Track/Correlation Function
9. Predicted X-Y Location	Track/Correlation Function
10. Estimated X-Y Velocity	Track/Correlation Function
11. Geographic Area	Map File/Geographic Filter Function

A tracker design such as an adaptive α-β tracker or Kalman filter will provide the necessary estimation and prediction of aircraft position and velocity.

Related processing tasks performed are:

1. Geographic Separation

   The ability of the operator to select specific regions for track drop, track auto-acquisition, and track tagging resides in this function. A "map" consisting of x-y delineated areas resides in the map file allowing the processor to provide the sensor with the appropriate interrogation control commands to be applied by the DAS interrogation control logic within the specified region. Sophisticated airport surface-feature-to-target-location-matching will not be done in the TAGS hybrid as the radar target itself provides the actual position indication.

2. Lost Target Smoothing

   If a target is lost due to a disruption in sensor data, it will be coasted until automatically reacquired by the sensor reinterrogation procedure. If a target is permanently lost, it will be coasted for a specified amount of time and the data block will be frozen at the last coasted position and an appropriate symbol displayed.

3. X-Y Prediction

   The tracker predicted position will be sent via sensor control to the DAS interrogation control logic to assist it in its cell position update. The processor tracker provides a smoothed position update for display tag movement (1 sec update rate). Heading and course indication will not be computed for display purposes as the ASDE target will provide the heading and course indication.

4. Queue Lists

Traffic in areas designated as departure queues or arrival holding areas are added to a list displayed on a defined area on the display. See Figure 7.3-4. Data blocks can then be removed from all targets in the list to reduce display clutter. Targets selected for queue are distinguishable by map file coordinate matching and by zero velocity and proximity.

5. System Control

Central control of the particular system configuration which has been input by the supervisory controller concerning active runways, queue areas, search areas, etc. resides here. In addition, general system management tasks such as failure monitoring, system input and output and computer program loading are performed by system control in its function of coordinating and monitoring the other system elements.

6. Display Subsystem and Controller Input Interface

Data files containing x-y position and flight ID for use by the display subsystem are established and transmitted. The quick-look processing feature is coordinated here, with transmissions of data for one operator configuration mode to the particular console selecting the quick look feature. Message inputs from the PEM are processed and appropriate action taken.

7.3.4.4 Display Subsystem - The display subsystem receives processed data from the multilateration processor and combines it with raw (unprocessed) data from ASDE-3 on a single high-resolution bright-TV display. The display subsystem includes the operational controls consisting of the keyboard, PEM, and display controls described earlier.

7.3.4.4.1 Display Requirements - The following are key design requirements/goals for the TAGS hybrid display.

1. The display must be used in high ambient light conditions.
2. Both primary radar targets and A/N symbols must be displayed.

The only proven system for accomplishing items 1 and 2 is the raster scan converted bright display, the system currently planned for the TAGS hybrid.

3. Regardless of range scale and offset, precise registration must be maintained between the radar and multilateration inputs.

Registration is currently planned to be done by the use of calibration beacons located on the airport surface with corner reflectors colocated. On initial display set-up and occasionally thereafter, the controller will manually register these beacons/ radar targets on the display thus registering the multilateration system and ASDE-3 map data.

An inherent nonlinear source of sensor registration error is the slant range measurement of the ASDE versus the surface range measurement of the multilateration system. For a two-hundred-foot high ASDE tower the difference between slant range and surface range is 38 feet at a range of 500 feet. The registration error diminishes rapidly, becoming less than the typical multilateration error (20 feet) at 1000-foot range, and less than 5 feet at 4000-foot range. Depending upon analysis of the error impact, compensation may or may not be required (for example, a bias could be added to limit the peak error to ±20 feet from 500 feet to maximum range). Non-linear compensation is most logically done in the multilateration sensor system at the point where target x-y position is computed before being stored in memory by the processor. Sophisticated compensation using a computer stored map of airport terrain features could be done if required.

4. Target trail presentation should be controller selectable.

This goal will be satisfied if the digital scan conversion system proves feasible.

5. The system should be capable of displaying a wide range of character sizes (e.g., 1/8 in. to 1/3 in. in height on a 16-in. tube display) with high character integrity (i.e., display lines per height) for optimization in the tradeoff between large alphanumerics for a long viewing distance and small alphanumerics to limit data block overlap, of targets and other data blocks.

Two symbol presentation alternatives are available. Alphanumerics can be optically (via vidicon) scan converted from a stroke type display, or a digital processor can generate dot matrix alphanumeric video. Either alternative can be mixed with the primary radar video (either optically or digitally scan converted). These alternatives are discussed further in the following sections.

7.3.4.4.2 Display Legibility - The choice of character size for the tower cab display is a tradeoff between maintaining characters large enough for legibility at a 6-foot viewing distance versus their being small enough to minimize the occurrence of character overlap in the congested ramp areas. Character quality becomes a factor when character height shrinks to the size where a minimum acceptable number of TV scan lines per character height is used to form the character.

The analog method of character presentation reaches the minimum character size at 15-raster lines per character height.[13] For the 1000-raster line per 14 1/2-inch usable diameter display, this results in a minimum character height of 0.22-inch. The digital TV method (dot matrix generation of A/N for direct input to display) can provide equivalent legibility in a 7x9 dot matrix resulting in a minimum character size of 0.13 inch on the same 14 1/2-inch display.[14]

At a viewing distance of 6 feet the smallest allowable character size is about 1/4 inch, which maintains 13 minutes of subtended visual arc.* If the 6-foot viewing distance were the overriding requirement, the analog symbol would be adequate at 15 lines per alphanumeric height. However, the analog approach does not offer the ability to tradeoff viewing distance for reduced character size, thereby reducing overlap (display clutter), since the resulting loss in number of TV lines per character height would degrade symbol legibility. The digital technique allows reduced size characters to be used without loss in character definition. As shown in Figure 7.3-10 the operator has the option of selecting small characters (∿1/8 in.) to reduce display clutter, but has to walk within three feet of the display to maintain the 13 minute subtended angle. Clearly the digitally presented TV characters offer more display flexibility, although not simultaneously producing low display clutter (due to symbol overlap) and long viewing range.

7.3.4.4.3 Analog Scan Conversion Character Presentation - Figure 7.3-11 is a block diagram of one channel of the analog scan converted display alternative. Shown are the two independent PPI/vidicon pairs with decay characteristics tailored to suit the different target and symbol display requirements. Decay characteristics are fixed by the "studio" vidicon (fast decay) for A/N characters and the "sticky" vidicon (slow decay) for the radar targets, and are not operator adjustable. Independently adjustable brightness on a per-channel basis is available for map, background, character and target video.

A complete replication of the two-path scan conversion is required for each independently adjustable display channel. By providing a separately controllable non-additive video mixer for each independent display channel, independent control of the three video signals from the DEU (critical area, map and background) can

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*13 minutes lies between the upper limit of 16 minutes (Shartleff, ref 14), and a lower limit of 10 minutes (Devoe, ref. 13).

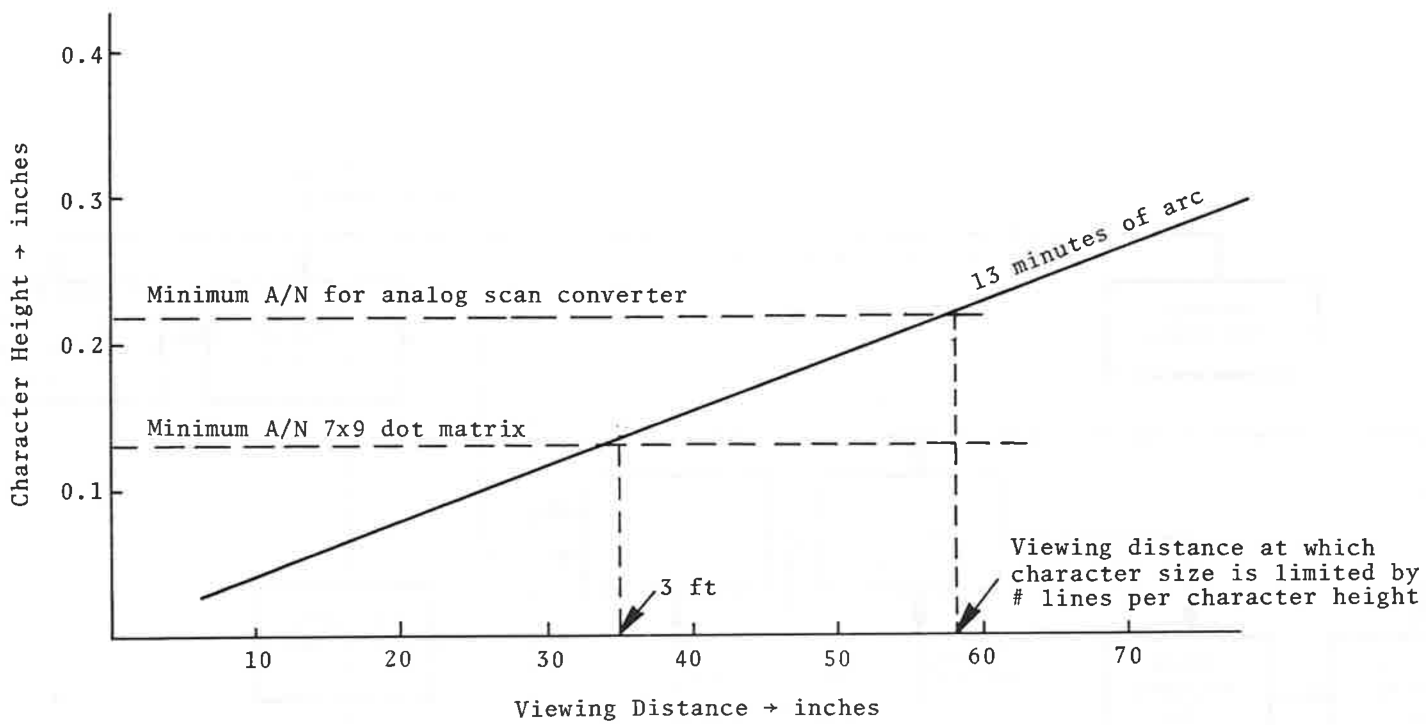

FIGURE 7.3-10. DISPLAY CHARACTERIZATION SIZE REQUIREMENTS FOR 14 1/2-INCH USABLE DIAMETER TV BRIGHT DISPLAY (1000 lines)

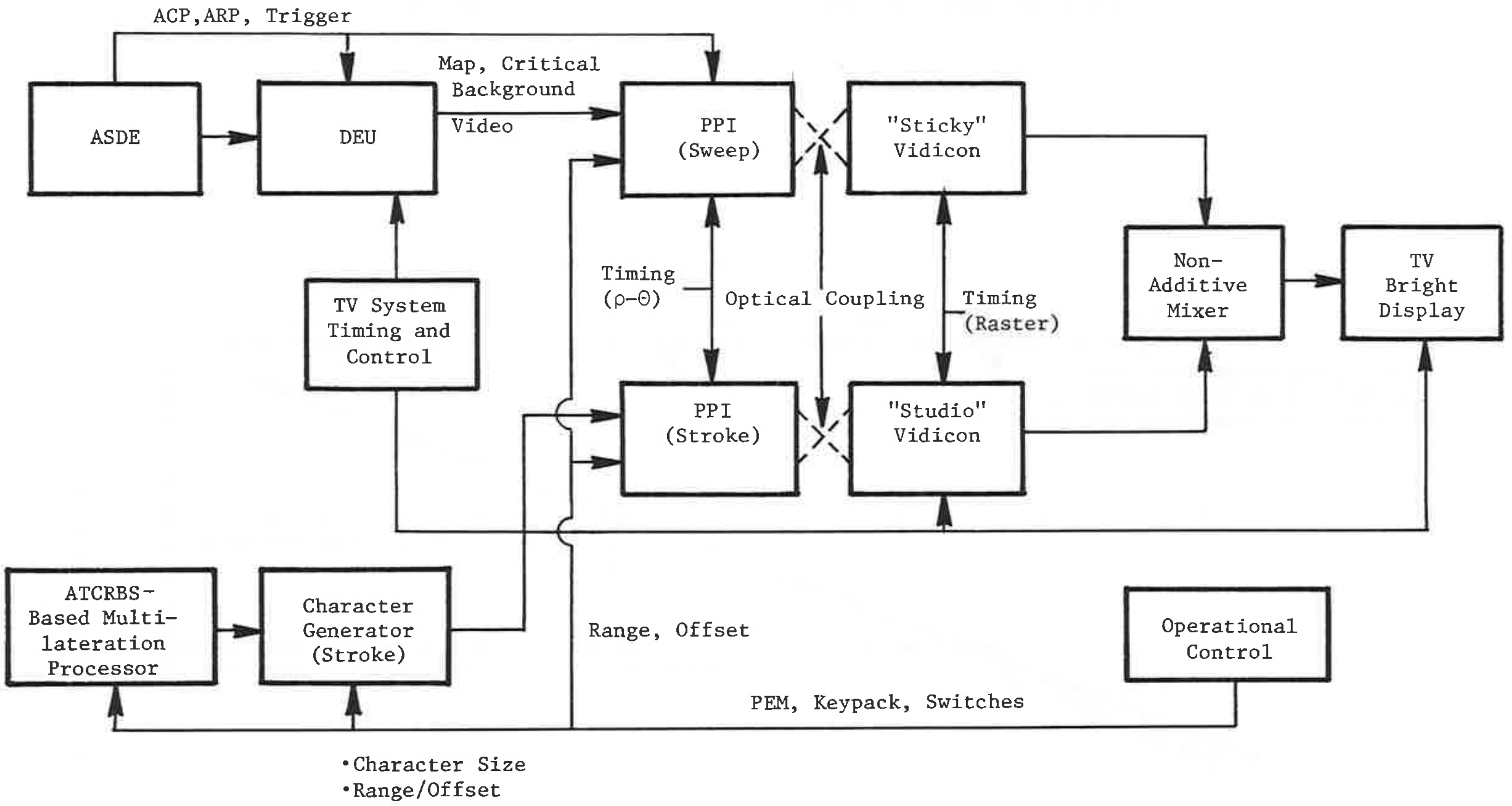

FIGURE 7.3-11. ANALOG SCAN CONVERSION OF A/N

be provided without the replication of the expensive memory portion of the DEU. Several TV monitors can be driven by any one channel.

The system of symbol and character generation shown is essentially as done in the ARTS Bright Alphanumeric Display System. Analog scan conversion implementation for ARTS was cost effective since the design of a stroke character generator for PPI presentation already existed for the ARTS. Using the same approach for TAGS would not be as economical particularly if no requirement exists for a direct view PPI. In addition, the major drawback of the analog conversion system is the relatively poor character legibility resulting from optically converted stroke symbols, dictating relatively large alphanumerics for legible viewing (≈ 1/4" AN). While the primary design requirements are met by the analog technique, the design goal of optimum character legibility versus display clutter is not met.

7.3.4.4.4 Digital Display Presentation - The all-digital implementation of the TAGS display subsystem is shown in Figure 7.3-12, including the digital scan conversion of ASDE video, the display enhancement unit and the digital alphanumeric generator from the TAGS processor inputs. Each of the three elements (DEU, DSC, and TAGS A/N) has its own solid state memory, necessitated by the asynchronous relationship between each sensor system and the TV display system. The operation of each of the memories is similar in that input information is written into memory as it becomes available (ρ, θ from radar, randomly from the TAGS processor) and read out in synchronism with the TV display line format.

Figure 7.3-12 depicts the result of an evolutionary system development, where ASDE with its DEU and DSC exist prior to the addition of the TAGS sensor. This configuration is desirable since not all airports having ASDE would have TAGS. The primary interface consideration is whether or not non-additive mixing of ASDE video (including DEU map) and data block video is done digitally, requiring access to video internal to the DSC. With the

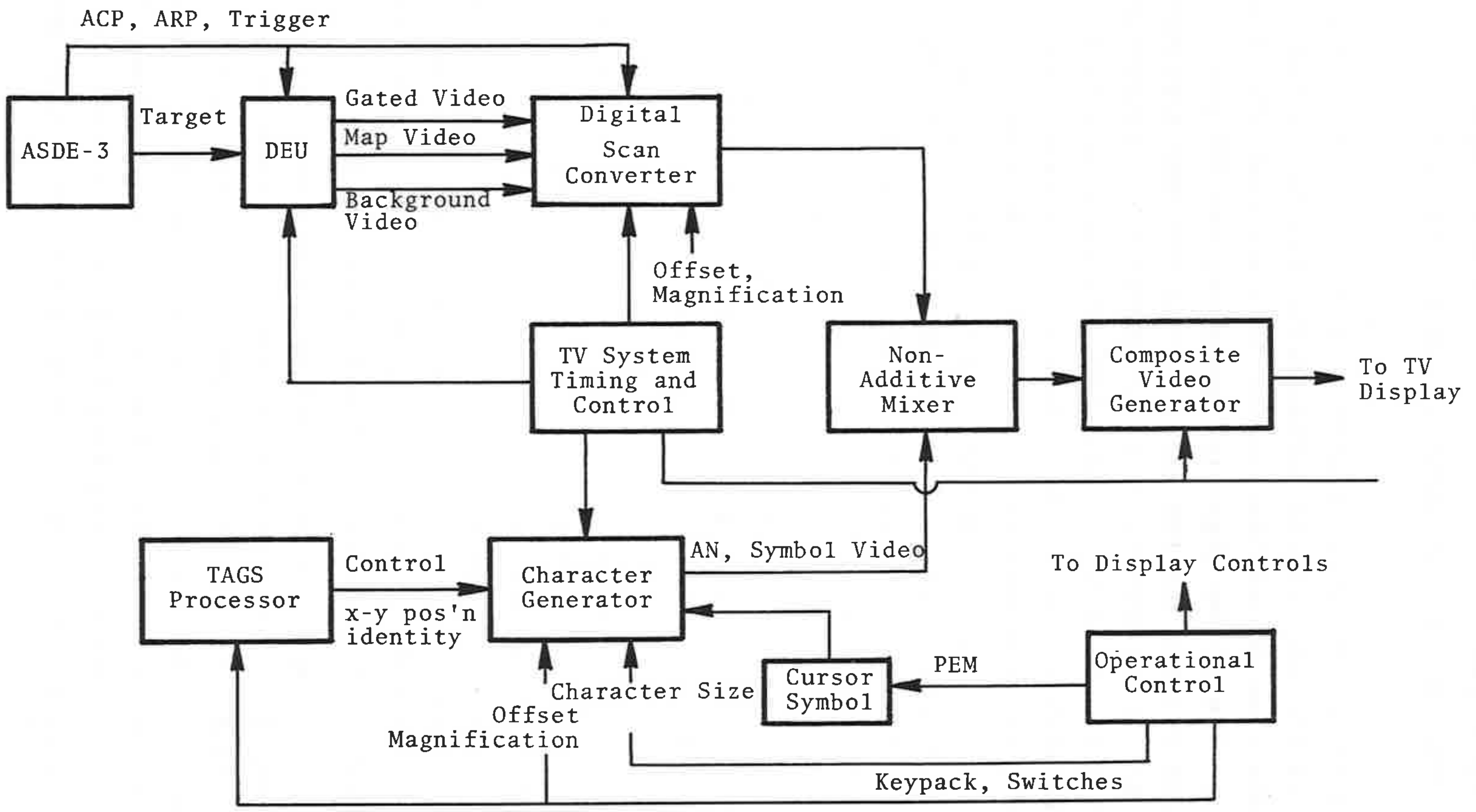

FIGURE 7.3-12. ALL DIGITAL TAGS DISPLAY SUBSYSTEM

analog scan converter in lieu of the DSC, the non-additive mixing of videos would be accomplished after D/A conversion.

The character generator receives location and identity information from the TAGS processor and generates A/N, leader and target symbol dot patterns (from read only memory) and stores the resulting pattern in a random access memory in TV line format. The information in the memory for each TV line is read out at the display scan rate, converted from parallel to serial, and mixed with the cursor symbol video for final output to the non-additive mixer as shown in Figure 7.3-12. The digital character generation technique provides the capability to meet the functional requirements discussed earlier (Section 7.3.2) and allows the character size tradeoff flexibility discussed in Section 7.3.4.4.2.

7.3.5 System Integration

The following sections present material which should be considered when integrating TAGS into the cab and with other MSDP elements.

7.3.5.1 External System Interfaces - To date, the ASTC program has considered the interface of TAGS with ARTS its major system interface. TAGS will require position, speed, course, beacon code, identity, and weight class on arrivals just prior to landing (e.g., as the RBS loses signal or at the middle marker) and, beacon code, identity, and weight class on each departure prior to push back (e.g., as flight data is received from the NAS computer or code assignment on a VFR is made from the cab). In addition, the ATCRBS interrogation sensor will operate in the dead time of the local RBS and will need to sense dead time. However, this latter interface is not significant since it is simply a receiver to sense the RBS interrogations. No other interface is required to operate TAGS in today's environment. No firm ARTS interface specifications or coordination has taken place to date due to the preliminary stage of TAGS development.

Several interfaces will have to be considered in the future MSDP environment. Since TIPS, TAGS, and ARTS perform three separate functions, the possibility exists that three separate computer systems may exist in the terminal environment. From both a computational and interface standpoint, the design of TAGS will have to be closely coordinated with the TIPS. Areas requiring attention include:

1. Potential processor commonality between TIPS, TAGS and ARTS.
2. Consideration of mutual failure and backup modes.
3. The replacement of the planned ARTS interface (described above) with a TIPS interface.
4. Possible joint use of keyboards by TAGS, TIPS and the ARTS BRITE.
5. Potential use of shared TAGS/TIPS displays at TAGS sites.
6. Potential use of TIPS functions (e.g., handoffs, resequencing of data lines) by TAGS.

Another important potential interface is with DABS. DABS is being designed to operate in the environment of the RBS as is ATCRBS trilateration. Care will have to be taken to assure there is no interference between DABS and the trilateration system and between either system and the existing RBS. In addition, consideration will have to be given to the use of DABS by TAGS.

The ATCRBS trilateration system relies on spatial interrogation (i.e., the successive interrogation of small geographic cells) to interrogate one aircraft at a time. If practical for surface operation, DABS could interrogate DABS transponders on surface traffic one at a time through discrete address. This method of interrogation would be simpler than the spacial interrogation and therefore a wholly DABS based sensor might be cheaper than the ATCRBS based sensor. However, until all or nearly all aircraft operating into the TAGS sites are DABS transponder equipped, a wholly DABS based system would give up important identity data (available via ATCRBS). Therefore, TAGS will be initially installed with the ATCRBS based sensor. Once an ATCRBS based TAGS is installed, it is unlikely that the addition of a DABS interrogation mode would be cost effective until the ATCRBS based sensor wears out. However, as the percent of DABS equipped aircraft approaches 100 percent, problems may arise which would justify a switch to DABS (e.g., RBS timing limitations). Studies of such problems have not been conducted to date.

Two systems which might affect Local Control and, therefore, TAGS are Microwave Landing System (MLS)and Metering and Spacing (M&S). These systems have not been considered by the ASTC program in any detail. The wide coverage in azimuth will provide for curved approaches during IFR. Curved approaches will reduce the effects of noise and the path length (and approach time). However, the duties of Local Control, (a) to assure each arrival will exit the runway before the next arrival will land and (b) to clear departures between successive arrivals, may be adversely affected by use of curved approaches. Time-to-threshold of each successive arrival may be more difficult to estimate with varying curved approach paths. This problem could be compounded by M&S which will space more (than the current manual system) arrivals near the minimum separation standards and may permit reduction of the standards. To aid Local Control, time-to-threshold information may be required. This information could be computed by the TAGS (based on an automatic data transfer from ARTS) and displayed on the TAGS local controller display. However, this concept (described in the next section) has not been viewed with favor by FAA Air Traffic Service personnel (both Terminal Branch, (AAT-120) and field personnel) and TAGS would not be available at all M&S locations. Therefore, it is most likely that if such information is required by Local Control, the information will have to be generated by M&S and displayed via the ARTS BRITE.

In addition to spacing for minimum separation (to improve arrival capacity) M&S will leave spaces for departures on dependent arrival and departure runway configurations. This can be done by using the current procedure. As the departure demand grows and a departure queue builds up, the cab supervisor can call to the TRACON to ask that arrival spacing be increased. This could then simply be entered by keyboard into ARTS for M&S use. However, if TAGS is present, this function could be automated by an automatic data transfer of departure demand to M&S. At the present time, such an interface is not planned and has not been studied.

The operational interface between the Wake Vortex Advisory System (WVAS) and TAGS is expected to be slight. However, a physical interface of field equipment may be important. Both WVAS and the ATCRBS trilateration sensor will require towers on the airport surface. WVAS will require meterological towers. Trilateration will require interrogator and receiver stations. Both systems will require power and communications to the tower. If RF interference is not a problem and mutual siting can be worked out, joint use of surface towers should be made. No detailed studies have been made to date by the ASTC program but should probably get underway soon to precede the WVAS deployment.

7.3.5.2 Integrated Local Control Display - During a TAGS field survey of five airports (Boston, New York-J.F.K., Atlanta, Los Angeles, and San Francisco) a concept for a local control display which would integrate airborne and surface information was discussed with FAA field personnel.[9] The display was not intended as a BRITE replacement which would continue in use to permit surveillance of the terminal area and control of overflights, missed approaches, and helicopter operations. The intention was to permit normal control functions to be conducted from a single display, thus simplifying the controller's normal scan pattern (otherwise including the TAGS, the BRITE, and the flight strips, and the window). In addition, the display would be configured to provide timing information to aid in the control functions.

The basic elements of the system as described in the field survey are as follows:

1. A linear range-to-threshold scale is added to the active arrival runway (or runways). It is drawn as a single line extension of the runway with one-mile range marks and a coverage of eight miles. The presentation would have one mile of airborne scale equal to about 700 feet of surface scale. Bearing to the arrivals would not be displayed. Each target would be shown on the single line extension. With this format time-to-threshold could be estimated and displayed as an option to range-to-threshold. Time-to-threshold estimates could be especially useful with the introduction of M&S and/or MLS with curved approaches.
2. Two controller adjustable benchmarks were added to the range scale to assist in making routine decisions during the runway operation cycle. For example, a benchmark could be set to indicate the range- (or time-) to-threshold for the next arrival within which a departure should not be cleared to depart.
3. A clock was displayed off the end of the departure runway (or runways) depicting the time since the last departure began its takeoff. Also shown was the course and identity of the last departure. This information was intended as an aid in interdeparture timing for heavy aircraft.

The response of the field personnel to the integrated local control display was generally unfavorable. Of the airports surveyed, only Boston thought it might be useful on their dependent intersecting runway configuration. Tower personnel felt that the range information would be compromised by the small scale required to add range to the surface display and so preferred the BRITE. In addition, no particular value was placed on time-to-threshold. Range information as is now used was preferred.

7.3.5.3 Interfaces with Controllers - TAGS will have its greatest impact at the Ground Control (GC) position. The TAGS concept that is implemented (see Sections 7.3.1 and 7.3.2.) will affect the quality of the data presented, but in general, all concepts will display the same data; i.e., a plan view presentation of runways and taxiways, a shaped bright spot for each target return, a data block associated with each target by a leader line, and selected tabular listings. The one exception to this generalization is that target shape and extent will not be displayed if the fully synthetic display concept is implemented (Section 7.3.1). This display will not show the controller whether an aircraft's nose or tail is clear of an intersection.

Likewise, in most proposed configurations, target acquisition (the association of identity and flight plan data with aircraft position data) will be automatic. Again there is an important exception. In the digitized ASDE-3 concept (Section 7.3.1) the controller must manually acquire every ground traffic target that is not a recent arrival. For each such target, the controller must enter the data code , move a cursor onto the target using a joystick, and press an entry button. In other configurations this procedure may be required for some VFR flights.

The GC function currently involves the use of flight progress strips for advance information and for memory of lineup sequence, radio position reports and direct visual surveillance for verification and monitoring, supplemented sometimes by ASDE or Low Light Level Television (LLLTV) when visibility is poor. TAGS will effectively replace radio position reporting, flight data strip manipulation for lineup sequencing, and the ASDE-BRITE backup display. Visual surveillance from the windows, when possible, will still be the primary mode of traffic monitoring, for the TAGS display at best will show only a part of the real-world situation. The degree to which a controller may come to rely on the TAGS display instead of the window cannot be predicted and should be monitored closely in the first year of operational use.

The Local Control (LC) function will also make use of TAGS, particularly for control of aircraft moving on or near runways. As with GC, TAGS will reduce the LC's needs for flight progress strips and radio positioning reporting and will provide a better backup display for conditions of poor visibility. However, TAGS will add an additional display device to LC positions, since it will not replace the ARTS-BRITE functions, particularly the display of arriving traffic. Also the TAGS control panels, keyboard, and PEM will be added to an already crowded workplace without any compensating removal of equipment. The introduction of TIPS can further complicate this situation.

Serious consideration should be given to display and control integration at the LC position. Considerable space could be saved if a single display device could be used to show, selectively, either the ARTS III or the TAGS display. A single keyboard should be possible, as well as an integrated function selection panel, for ARTS-TAGS-TIPS combined. Consideration might also be given to a division of TAGS control functions into a panel of frequently used controls at the LC position and a panel of controls generally set once and left for a period of time to be located elsewhere in the cab where space is less of a premium.

As discussed in Section 7.3.3.5, only short and simple lists of tabular data can be accommodated on the TAGS display. The LC will have the tabular listing capability of ARTS III available to supplement this feature. The LC and the GC may very likely have a TIPS display also available, with a greater capacity for presentation of alphanumeric data. Should controllers have more than one tabular listing display available, they could standardize the selection of which lists would appear on which displays to reduce search time for specific items of information.

A greater reliance on CRT displays will increase the frequency with which controllers must look away from the windows to read a display or vice versa. Each change of direction of vision will entail some degree of visual adaption. In the daytime, a rapid but uncomfortable light adaptation will occur each time vision is transferred from a scope to a window, and a slower dark adaption will be required each time the controller looks away from a window to read a display. At night, the lights and lighted areas to be monitored outside the cab will be nearer the level of scope brightness, but some adaptation will still be required. The combined effects of adaptation-induced visual fatigue and the time lost during adaptation on controller performance and the variability of these effects with conditions of external visibility should be studied before TAGS becomes operational.

In summary, the introduction of TAGS equipment into the tower cab will provide considerable assistance to the GC and LC functions, particularly when outside visibility is poor. The principal problems for controllers that TAGS may introduce are crowding of workspace, additional tasks associated with adjustment of display parameters and selection of data, more display area to be monitored, and more frequent visual brightness adaptation. These problems can be solved through development of display and control equipment that integrates the functions of ARTS III, TIPS, and TAGS, and through controlled experiments in which tasks, layouts, and levels of illumination are realistically simulated.

7.3.6 Failure Modes

As discussed in Section 7.3.1, the two dissimilar sensors of the hybrid approach tend to improve system reliability. If the ASDE-3 system fails, location and identity of all aircraft are maintained. If the ATCRBS sensor fails, location on all targets is maintained with only identity lost. In the event that both systems fail, the cab controllers will have to revert to pilot position reports via voice channel for surface surveillance. Operations would be slowed down accordingly.

The only external interface which would be critical to TAGS in today's environment is ARTS. Should the ARTS system or ARTS/TAGS interface fail, flight identity and beacon code correlation data would not be available. In addition, arrival data needed to estimate an arrival's runway and time-of-arrival on the runway would not be present for automatic arrival acquisition. For the second problem, this would simply mean that arrivals would be acquired on the slow scan. The controller might have to wait as long as 15 seconds to get the identity of an arrival. This would place the arrival about one third of the way down the runway (i.e., average runway occupancy during landing is approximately 45 seconds) and would pose little or no problem. However, loss of beacon code and identity correlation would be a problem. TAGS could display beacon code which could be manually correlated with flight identity by using flight progress strips, however, such correlation would be an added workload. Manual entry would be possible but this too would add workload. The only complete solution would be a back-up source for code and identity correlation.

One possible back-up source would be the NAS computer. A line could be tied to TAGS to deliver IFR beacon code and identity correlation in parallel with ARTS. This information would only be used if total fleet (IFR and VFR) data was not available from ARTS. At the large TCA airports, which TAGS is likely to serve, this would address the majority of aircraft. No coordination or detailed study of back-up sources for beacon and identity correlation has been conducted to date for TAGS.

7.4 INTEGRATION ISSUES SUMMARY

The following is a summary of issues for consideration in integrating ASTC systems into the cab and with other UG3RD elements. The items are drawn from Sections 5.1, 5.2, and 7.0.

1. Both the BRITE-4 and NU-BRITE are large (19 inches wide by 19 inches high by 27 inches deep) heavy (100 lbs.) displays which can be difficult to locate conveniently for controllers. In many instances the display is hung overhead requiring the controller to look up at it, out on the airport, and down at his flight strips; a rather poor, high work-load scan pattern.

2. The A/N keyboard for the ARTS BRITE is used quite often by Flight Data (or Clearance Delivery) to request TCA/VFR beacon code assignments. However, a BRITE display may not be conveniently located for Flight Data. A small CONRAC monitor (i.e., 10-inch tube) has been used for Flight Data with success at some cabs but this is a local solution. A system wide solution appears warranted.

3. ASDE-2, particularly with a poor bright display, is placed low on the priority list when it comes to allocation of cab space. The displays and control units, therefore, can be inconventiently located for some of the controllers. In addition, often one and at most two independent display units are installed so that presentations are usually shared by controllers. This limits the effectiveness of the NU-BRITE control head features.

   If the trend in ASDE display installation continues for ASDE-3 and TAGS, the effectiveness of both systems will be compromised. TAGS, in particular, will require independent display channels for each ground controller. This requirement for added ASTC displays will come along just as other MSDP elements are proposing to add displays. This could pose serious installation problems. Since TAGS will be present in relatively few cabs (four to nine) a study of at least the basic four cabs (Chicago-O'Hare, Los Angeles, Atlanta, New York-JFK) might be warranted to develop detailed plans for the integration and installation of the MSDP elements. The study would include individual station layout analyses and would be applicable, in varying degrees, at other categories of cab (e.g., where ASDE-3 would replace TAGS).

4. In at least four major cabs, TAGS, TIPS, and the ARTS BRITE will co-exist. Consideration of common equipment should be given prior to TIPS and TAGS development. Areas to consider include:

a. Potential processor commonality. If TIPS does not use an ARTS IOP but uses a new processor, care should be taken that TAGS does not require a third kind of processor and its attendant maintenance and training costs. If TAGS cannot use an ARTS IOP, the new TIPS processor should be specified to meet the needs of TAGS as well.

b. Potential keyboard commonality. TIPS and TAGS both plan to use an ARTS BRITE type keyboard. This could mean up to three similar keyboards at one station, Local Control. Consideration should be given to combining all functions in one keyboard.

c. Potential display commonality. TIPS and ASTC (ASDE-3 or TAGS) displays will be added to the current cab equipments (including BRITE). This would require three large CRT displays for Local Control and two for Ground Control. If displays could in some sense be functionally shared, a space saving could be made and the controllers scan pattern improved.

d. TAGS could operate with an ARTS interface as described in Section 7.3.5. However, a TIPS interface might be preferrable. Information available from ARTS may be available from TIPS and, in addition, TIPS functions could be used in TAGS display format development (e.g., to establish those targets being controlled at a given position for tagging with data blocks).

5. Coordination should be done between TAGS and DABS development activities. It is not likely that TAGS will use DABS, however, both systems will impact on the ASR/RBS dead time which may be at a premium.

6. MSDP elements and other new equipment which will require that equipment be located on the airport surface should be coordinated for common siting possibilities. Examples are TAGS, with its ATCRBS interrogation and

receiver stations, and WVAS, with its meteorological towers. Both system sites will require site preparation, service roads, power and communication lines to and from the tower. Common siting could aid maintenance and reduce installation costs. In addition should the sites require towers (as with the examples), they should be kept to a minimum for safety.

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8. TERMINAL INFORMATION PROCESSING SYSTEM (TIPS) AND THE TOWER CAB

8.1 INTRODUCTION

8.1.1 Background of TIPS Program

The TIPS program began in 1972 following an Office of System Engineering Management letter of guidance to SRDS suggesting an organization and division of responsibilities for the development of terminal flight data handling (TFDH) automation. By the spring of 1973, a TFDH Automation Development Plan was completed and work began on tower cab automation concepts and analytical studies on reliability, communication channel loading, and cost tradeoffs. By mid 1973, this work was completed and the resulting tower cab design concept was demonstrated by means of simulation.[1] Based on that concept, AAT issued a form 9550 in August of 1973 requesting SRDS to develop a more efficient means of flight data handling for the high density ARTS III terminal areas that would replace the current system based on the FDEP.[2]

In the letter transmitting the form 9550, Air Traffic Service suggested a short, medium, and long range plan for replacing the FDEP subsystem at all terminal facilities with an improved method of data handling.[2] Specifically:

Short Range Plan

Cure present FDEP problems by upgrading circuits and making hardware and software modifications

Medium Range Plan

1. Develop a flight data system for high density ARTS III terminal areas that would provide an automated flight data handling capability to radar controllers and to non-radar controllers at primary and satellite tower cabs.
2. Modify the system developed for high density ARTS III terminal areas so that it would be suitable for medium activity ARTS III terminal areas.

Long Range Plan

3. Provide a more efficient flight data dissemination method, preferably without automation, for ARTS II and non-radar control towers.

In addition to this plan, the letter also stated the operational requirements that the Air Traffic Service (AAT) wanted the flight data system to satisfy. Specifically:

"1. Controller actions for input, output, and transfer must be kept to an absolute minimum. These actions must be no more than those required of a controller in the present manual system.

2. Presentation must be consistent with terminal procedures and make no unusual demand on either the user or the facility.

3. Display of data of a size and intensity that is completely legible at normal viewing distances.

4. The system must be capable of passing data on a discriminate and selective basis so that only the data required at a particular position would be presented; however, the capability must exist to call up the full flight plan.

5. The controller must be provided the capability of rearranging, adding, changing, or deleting information as necessary.

6. Displays must be designed to present data in the most usable and sequenced form either on the radar display, digital display, or both.

7. Equipment such as keyboards and displays must be easily accessible to the controllers and designed to fit the limited space available at the control position.

8. The system must be flexible to permit combining and/or decombining positions of operation, as required.

9. System must be modular in design to permit expansion and growth capability.

10. The system at proposed enhanced ARTS III locations must provide fail safe and fail soft capability. In other terminals, as a minimum in the event of a system failure, the last data presented on the display should be retained.

11. Since this would eliminate strips or hard copy, the capability must also be provided to record and store data for future reference and review.

12. The capability to collect and compile statistical data should also be provided.

13. The capability to communicate with adjacent ARTS III sites must exist."

In response to the AAT request, SRDS put increased emphasis on developing an automated flight data handling system for high activity ARTS III terminal areas - TIPS. In 1974 two activities were carried out by SRDS that formed the basis for identifying current TFDH problems, for establishing terminal flight and control data requirements, and for generating an automated tower cab design concept. These activities were a field survey of the TFDH systems at 6 ARTS III facilities (Houston, Boston, Los Angeles, Baltimore, Washington National, and Las Vegas) and a national conference on TIPS.[3,4] The conference brought together the TIPS designers and the planning officers from the Air Traffic Service regional offices from across the country for an exchange of views on TIPS.

Since 1975, SRDS has been sponsoring studies of a TIPS prototype system, including an analysis of various configuration alternatives. The prototype system will be used for field evaluations of the TIPS concept. SRDS is currently completing a report which will describe the prototype system and its engineering and functional requirements.[5]

8.1.2 Overview of the TIPS Concept

The concept described in this section is based on an early draft of the system description that will be included in reference 5. Therefore, the details of the following system description must be considered as preliminary and subject to change.

TIPS will accept, process, distribute, and display flight and non-radar data for an entire terminal area. The system will replace the tray of paper flight strips at each tower cab and TRACON control position with electronically displayed data on a new tabular display. Figure 8.1.1 shows a simplified block diagram of TIPS and its primary interfaces.

TIPS will interface with the host NAS computer and the ARTS III computer by means of the Terminal Flight Data Processor (TFDP). This processor will be co-located with the ARTS III computer and will maintain the data base of flight and other non-radar data for the entire terminal area. The data base will be made up of flight data provided by the host NAS computer and by the terminal area controllers by means of their individual keyboards. The stored data will include all terminal flight plans and control information such as IFR flight plans, VFR flight data (e.g., TCA related information), airport status, Notices to Airmen (NOTAMS), active runways, Automated Terminal Information Service (ATIS), and meteorological data. In addition to maintaining this data base, the TFDP operational program will process and route incoming messages to their proper destinations, will provide flight data to the host ARTCC, TRACON, and client control towers in a timely manner, and will automatically compute runway assignments for operations at the client control towers.

TIPS has developed a scheme for routing data from one control position to its handoff control position that requires a minimum of button pushing on the part of the controller. This scheme is based on TIPS having knowledge of the runway assignments of the arrival and departure operations in the terminal area. To reduce the number of runway assignments that controllers would be required to input to TIPS, TIPS will automatically compute and display the routine runway assignment for each arrival and departure operation. Only when the assignment is in error would a controller be required to make an input to TIPS.

The Terminal Flight Data Processor will interface with a set of display processors. There will be a display processor for the TRACON and one for each client tower cab being serviced by TIPS in the terminal area. Each display processor will maintain the

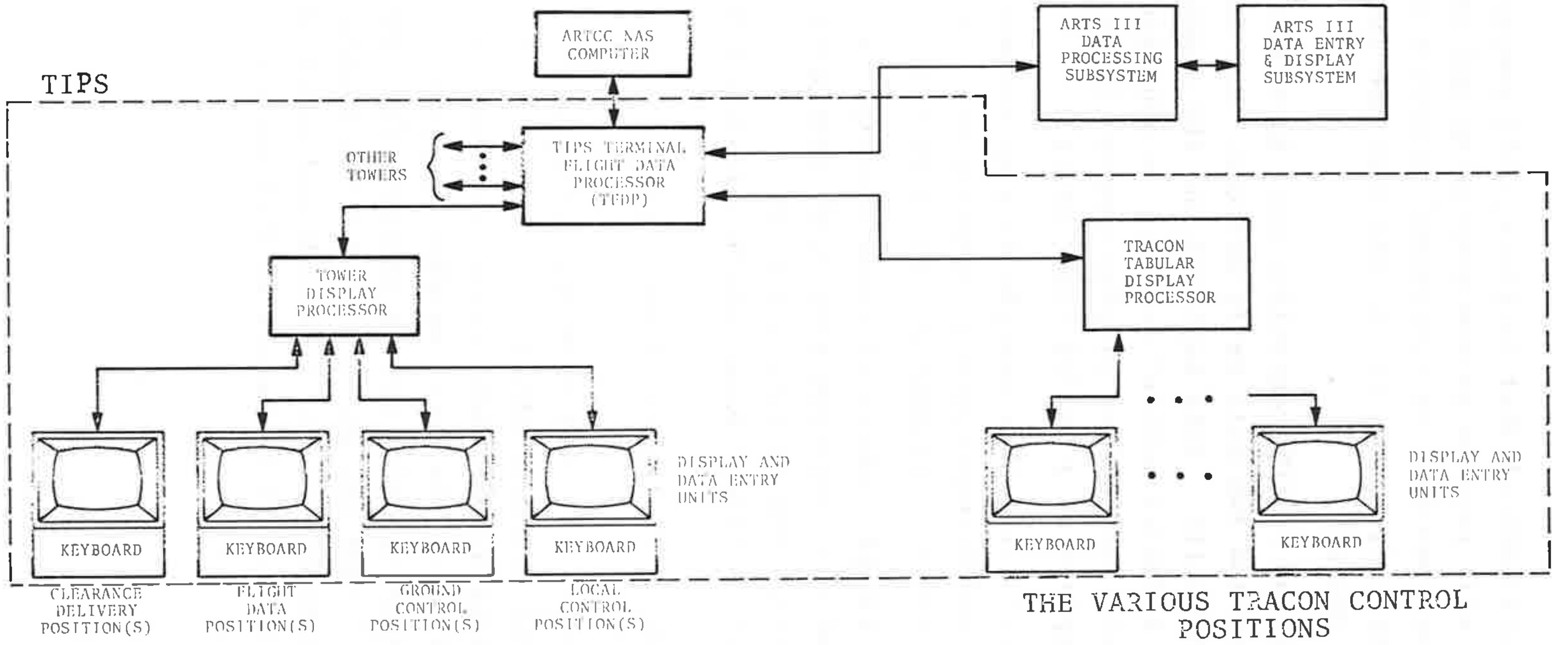


FIGURE 8.1-1. SIMPLIFIED TIPS BLOCK DIAGRAM

TIPS display presentations at that facility, will process controller inputs and will perform system monitoring and control functions. The processor will be programmed to permit operational positions to be combined, split, or shifted from one display and data entry unit to another.

Each tower cab and TRACON controller will have a tabular display for flight data and two data entry devices. One data entry device will be an ARTS III - like keyboard and the second data entry unit will be a "quick action" device. In addition, TRACON radar controllers will be able to display summary flight data on their Plan View Displays on a "quick look" basis.

Figure 8.1-2 and 8.1-3 show example display presentations for Clearance Delivery and Ground Control, respectively. At each tower cab position the TIPS display presentation will provide:

The list of flight numbers of those vehicles currently under the control of that position along with pertinent information on these flights, such as aircraft type

An area in which flight plans can be displayed (i.e., FP READOUT)

An area in which the keyboard entry can be seen (i.e., PREVIEW AREA)

An area in which the TIPS computer can respond to a keyboard entry (i.e., COMPUTER RESPONSE AREA)

An area to display pertinent status information

An area to display the local weather and time

Area(s) containing quick action controls for routine data manipulation. The format and operation of these display presentations, along with those for the keyboards and quick action entry devices, are described in detail in Section 8.2.

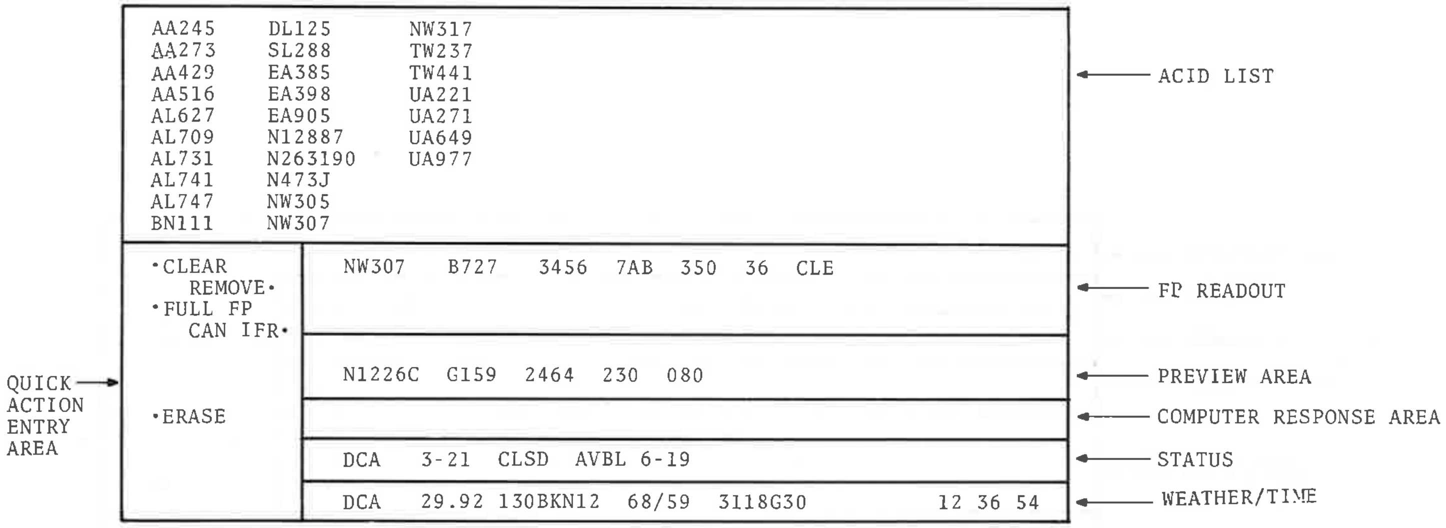
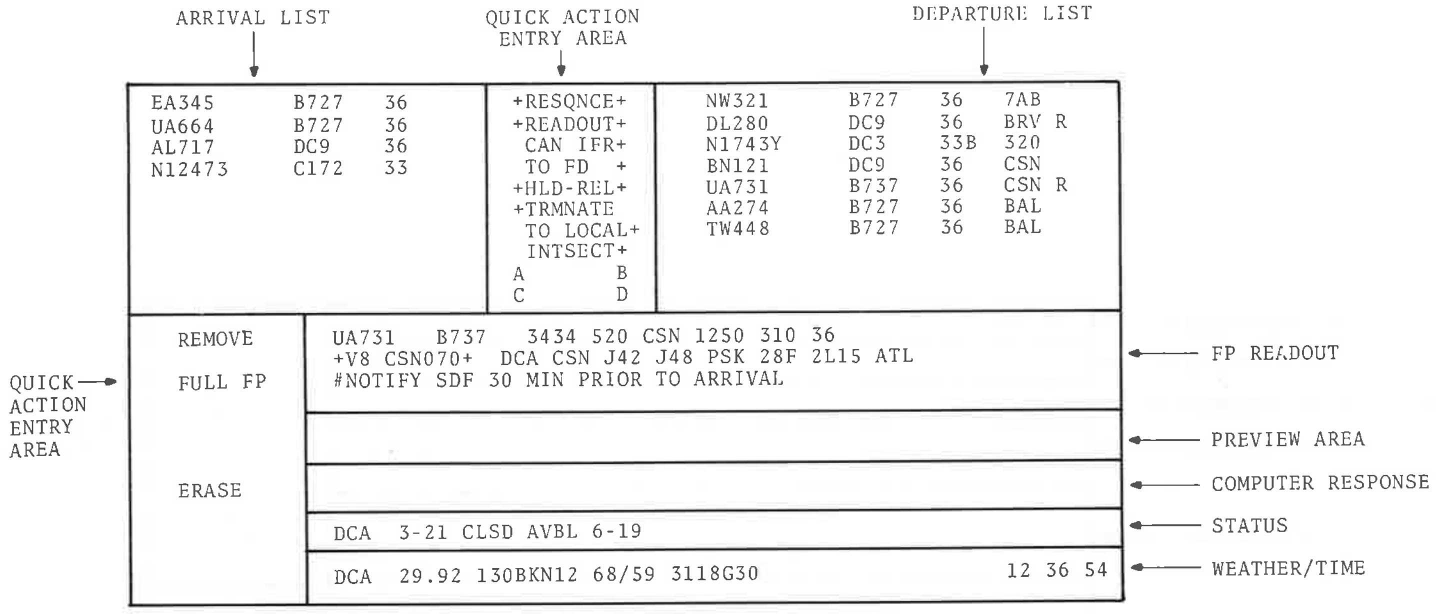


FIGURE 8.1-2. EXAMPLE OF TIPS DISPLAY PRESENTATION FOR CLEARANCE DELIVERY



```
EA345      B727   36      +RESQNCE+     NW321    B727   36    7AB
UA664      B727   36      +READOUT+     DL280    DC9    36    BRV R
AL717      DC9    36       CAN IFR+     N1743Y   DC3    33B   320
N12473     C172   33       TO FD   +    BN121    DC9    36    CSN
                          +HLD-REL+     UA731    B737   36    CSN R
                          +TRMNATE      AA274    B727   36    BAL
                           TO LOCAL+    TW448    B727   36    BAL
                           INTSECT+
                          A        B
                          C        D

REMOVE      UA731   B737   3434 520 CSN 1250 310 36
            +V8 CSN070+  DCA CSN J42 J48 PSK 28F 2L15 ATL
FULL FP     #NOTIFY SDF 30 MIN PRIOR TO ARRIVAL



ERASE

            DCA  3-21 CLSD AVBL 6-19

            DCA  29.92 130BKN12 68/59 3118G30          12 36 54
```

FIGURE 8.1-3. EXAMPLE OF TIPS DISPLAY PRESENTATION FOR GROUND CONTROL

8.1.3 TIPS Design Features

The TIPS Program lists the following as the system's major design features:

1. Centralized Terminal Fight Data Base. Any IFR or VFR flight data located in the centralized terminal data base can be displayed almost immediately after it is requested by an operator. (Flight data which must be obtained from the en-route flight data base will take slightly longer to be displayed). The flight data available to TRACON and tower controllers is identical.

2. Separate Processing System. Most TIPS processing, including the maintenance of the centralized terminal flight data base, will be performed in a new, separate processing system. This system will interface with the host ARTCC and co-located ARTS III computers. Selection of this system design minimizes the changes required to the existing terminal software.

3. Minimum Impact on Existing ARTCC Software. The messages currently sent by the ARTCC software to the FDEP will be sent to TIPS, and the message types received from the FDEP will be received from TIPS. No other significant changes are required to the ARTCC software because of TIPS.

4. Moderate Impact on Existing ARTS Software. Presentation of summary flight data to radar controllers on their Plan View Displays on a quick look basis will require changes to the ARTS display software. To the extent practicable, other TIPS functional changes will be incorporated in the new TIPS computers, rather than be added to the existing ARTS software.

5. Expandability to Additional Towers. TIPS can readily be extended to the smaller towers within the terminal area, providing them with needed flight data while eliminating any need for routine voice communication with the TRACON.

6. Applicability to All Terminal Areas. TIPS is suitable for all levels of terminal or tower flight activity. The same system hardware elements and computer programs will be used in all cases. Small facilities will have fewer displays and a smaller data base than large facilities. Differences between facilities will also be reflected in adaptation software.

7. Use of Low Cost Technology. TIPS can take advantage of recent technological advances which involve large scale integration (LSI). TIPS will use new low cost data processing hardware for most of its functions.

8. Failure Mode Provisions. TIPS will include a fail-safe capability (i.e., redundant equipment) at those large facilities where it can be justified. At all facilities, a TIPS processing or communications failure will not affect existing display information, and the failure of one display unit will not affect other display presentations. A backup capability using FDEP will also be maintained until confidence in TIPS performance and reliability is established. The FDEP equipment can then be removed, thereby eliminating maintenance and communication costs.

8.1.4 TIPS Operational Capabilities

The TIPS Program lists the following as the system's major operational capabilities:

1. Tower Electronic Tabular Displays. These are provided at all tower operational positions and will contain selected flight, weather and status information which is of current interest to the controller. The displays will also present full flight plan information in response to an operator request. The displays will reduce the amount of manual coordination required and improve the timeliness of data presented to the controller.

2. TRACON Flight Data Presentation. At each TRACON operational position, summary flight data will be displayed on existing Plan View Displays on a quick look basis, and flight, weather and status information will be displayed on a new electronic tabular display on a full time basis. The tabular displays will also present full flight plan information in response to an operator request.

3. Entering Local Flight Data. Local flight data will be entered into the computer data base for presentation on terminal displays. The operator will be able to enter VFR and tower en-route flight plans, change IFR flights to VFR status, and make

other flight data entries which relate to terminal area operations. (Unless these entries also affect en-route operations, the ARTCC will not be notified). Once the local flight data is entered into the TIPS computer, it can be displayed at any TRACON or tower controller position which needs the information.

4. Transferring Flight and Control Information. When control of a flight is transferred between the TRACON and a tower, a single operator action will usually provide the receiving controller with sufficient flight information, thereby eliminating voice coordination. When a flight is transferred from one tower controller to another, a single operator action will replace the physical movement of the flight strip from one controller position to another.

5. Adjusting Tower Manning Levels. In response to increases or decreases in flight activity, operator positions may be combined or split by a single supervisory action. When two positions are combined, the information displayed at those two positions will automatically be combined and presented on a single display. When a position is split, the information needed at the new position will be automatically presented on the new display, and the information needed at the original position will be retained on its display.

8.2 SYSTEM DESCRIPTION

This section describes the equipment that TIPS will introduce into the tower cab and discusses how that equipment would be used on a position by position basis. This description is based on an early draft of Reference 5, which should in be in final form and made available to the public by the end of 1977.

8.2.1 TIPS Tower Cab Equipment

Each cab controller will have a display and data entry unit which will consist of a tabular display, a quick action data entry device, and a keyboard. The cab will also be equipped with an Input/Output Terminal.

8.2.1.1 Tabular Display

The display hardware at all cab positions will be identical. The tabular display may be either a CRT or a solid state device. The unit's exterior dimensions will not exceed 12 inches H x 18 inches W x 14 inches D. The display will have three mounting options: desk top, built into the console, or ceiling hung. Figure 8.2-1 shows how the display would appear with a pedestal desk top mount. Regardless of the mount used, each controller will be able to pivot the display in its mount to suit his needs.

The character set used by the tabular display will include the twenty-six capital letters, the digits 0 through 9 and twelve special symbols such as the plus sign and period. The character set will be expandable to 64 characters. The displayed characters will be at least 0.21 inches in height and 0.12 inches in width. Characters of this size should permit viewing distances up to 6 feet. The display will provide good contrast for the entire range of light levels experienced in the tower cab.

8.2.1.2 Quick Action Data Entry Device

Those actions used most often by tower cab controllers will be implemented by easy-to-use"quick action" controls. The mechanization of this device remains to be determined.

One of the candidate mechanizations, and the one used in the functional and operational description of TIPS included in Section 8.2.2, makes use of touch sensitive areas overlying the display face. Data selection and manipulation is accomplished by the controller touching the designated areas on the display face with his fingers.

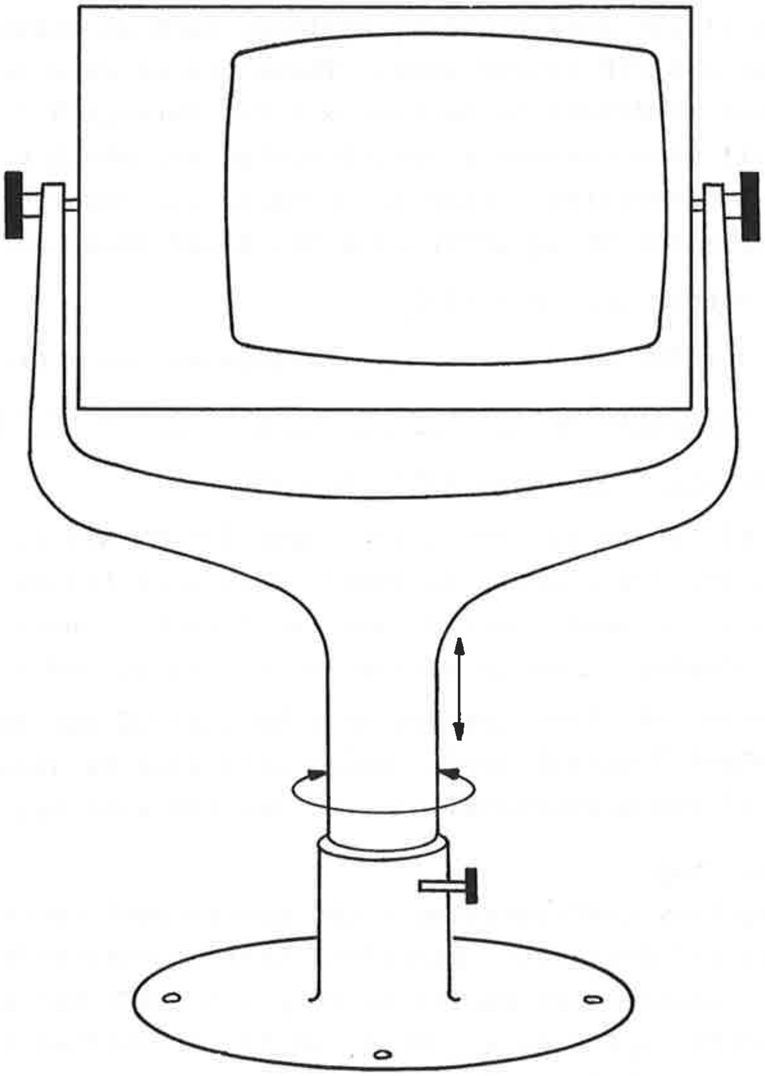


FIGURE 8.2-1. TIPS TABULAR DISPLAY WITH PEDESTAL MOUNT CONFIGURATION

8.2.1.3 Keyboard

An ARTS III type keyboard will be used by TIPS. The ARTS III keyboard panel measures approximately 8 inches in height and 8.75 inches in width. The keys will be non-locking and back-lighted. Key caps will be removable to facilitate legend changes.

The keyboards will have the standard complement of alphanumerics, special symbols (e.g., coma), and control functions (e.g., back-space). The keyboard will contain several function keys which will permit specific flight data handling options, such as submitting IFR flight plans and VFR flight data. These flight data functions will be described in detail in Section 8.2.2.2 through 8.2.2.5. The keyboard will also contain a multifunction key which will provide a growth capability. This key permits two functions to share one key by means of an upper case and lower case operation.

8.2.1.4 Input/Output Terminal (IOT)

The tower cab IOT will consist of a keyboard and a printer.

8.2.2 Functional/Operational TIPS System Description by Cab Position

8.2.2.1 Supervisory Control of TIPS from Cab

TIPS will eliminate the FDEP, the paper flight strip, and the strip tray from the tower cab. In their place each Flight Data, Clearance Delivery, Ground Control, and Local Control position will have a tabular display, a quick action entry device, and a keyboard. Supervisory control of these devices will be carried out by means of the Input/Output Terminal (IOT), which will also be located in the cab. Some of the operational uses of the IOT will be:

a. System Startup

b. Tower Position Configuration - the operational configuration of tower display and data entry positions will be controlled. With some exceptions, operational positions (e.g., GC, LC) may be combined (e.g., GC/LC), split (e.g., GC 1, GC 2), or shifted from one display/data entry unit to another.

c. Runway/Controller Assignment-if there are multiple GC or LC positions being staffed, each controller will be paired with an active runway. This pairing will permit the automatic routing of flight data from CD to GC and from GC to LC for departure handoffs and the routing of flight data from LC to the appropriate GC display for arrival handoffs.

d. Parameter Control Entries - the IOT will control such parameters as the time prior to proposed departure time that flight data is to be supplied to Flight Data and Clearance Delivery.

e. General Information Entries - text information can be transmitted to operational personnel at other ATC facilities.

f. Monitor the System.

8.2.2.2 Clearance Delivery Position

Clearance Delivery receives clearances for filed aircraft and delivers those clearances to the waiting pilots by means of the voice communication channel. In issuing a flight plan clearance, Clearance Delivery now uses flight data received from the Flight Data position in the form of paper flight strips. With TIPS, this flight data will come directly to Clearance Delivery and be presented on his tabular display. Figure 8.2.2 shows an example of the presentation.

Aircraft Identification (ACID) List

At a preselected time prior to departure time, aircraft with clearance will have their flight numbers displayed on this list. Clearance Delivery will have preselected how he wishes this list organized. The list can be organized according to (1) proposed departure time, (2) alphanumerically, or (3) by combining these two options so the list is alphabetical by company and then the company aircraft by departure time. In this example the list is organized alphanumerically. The list can hold 60 entries. Display paging will be used to permit this capacity to be exceeded. A prefix character for each ACID entry will indicate clearance type

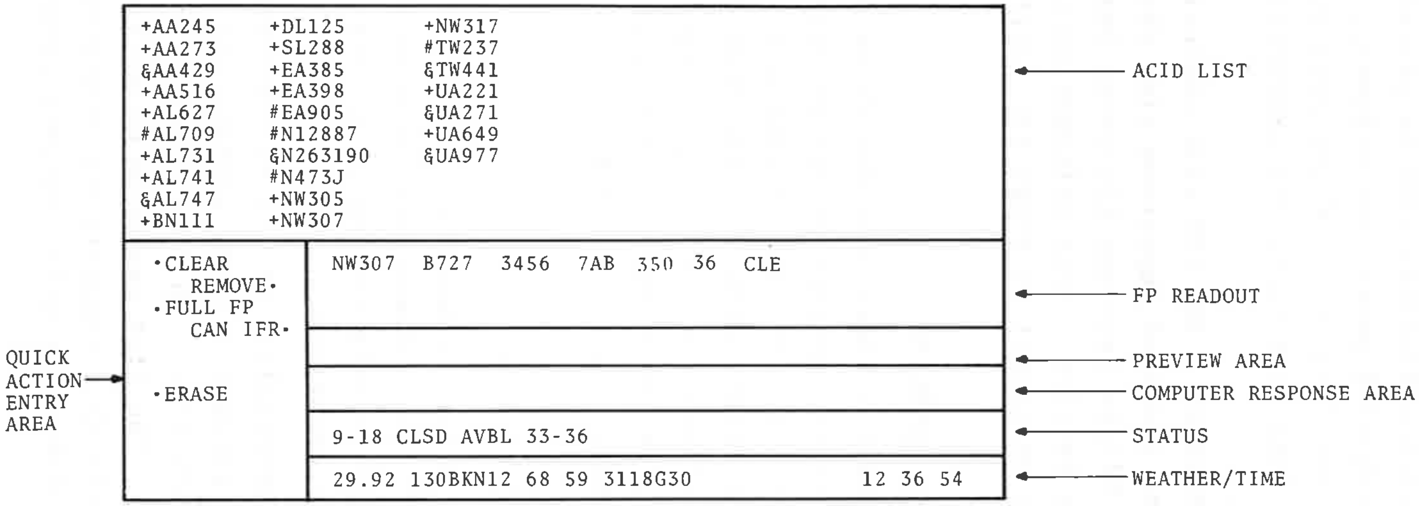


FIGURE 8.2-2 EXAMPLE OF CLEARANCE DELIVERY DISPLAY PRESENTATION

and clearance delivery status.

Plus sign - the flight has been cleared as filed

Ampersand (&)-the flight has not been cleared as filed and the full clearance should be read

Blank - neither cleared as filed nor read full clearance applies

\# - the flight has been issued its flight plan clearance, but has not yet been given pushback clearance by Clearance Delivery.

In the example display presentation it is seen that AA245 is cleared as filed and that AA429 requires its full clearance to be read. The example airport also has Clearance Delivery giving pushback clearance and AL709 has been given its flight plan clearance but awaits pushback clearance.

Flight Plan Readout Area

The controller can view the flight plan of any aircraft in the ACID List in this area of the display. The pilot can request the full flight plan or an abbreviated version.

In the example display presentation, Clearance Delivery has requested an abbreviated flight plan for NW307. The flight is a B727 aircraft with a beacon code assignment of 3456, is to depart over 7AB coordination fix, is to fly at 35,000 ft, is to takeoff from runway 36, and has Cleveland as its destination.

Quick Action Entries Associated with the Readout Area

The controller does his routine data manipulations by this means. There is an area on the display set aside for these touch controls. However, touch controls are not restricted to this area. The more important quick action controls for Clearance Delivery are:

Read - to display a flight plan in the Readout Area, the controller touches the appropriate flight number. If the aircraft is cleared as filed, an abbreviated flight plan will appear in the

Readout Area. If the aircraft is not cleared as filed, the full flight plan will appear.

Full Flight Plan - by touching this control Clearance Delivery will obtain the full flight plan for the aircraft already in the Readout Area. If the displayed full flight plan is of an extent to overflow the Readout Area, touching this control again will display the previously missing portion of the flight plan.

Clear - Once the flight plan clearance has been issued, Clearance Delivery can clear the Readout Area in preparation for another clearance delivery by touching this control. What happens, in addition to the clearance of the Readout Area, depends on the airport policy concerning CD granting pushback clearances from the terminal gates. If CD does not issue pushback clearances, the CLEAR action will cause the flight to be removed from the CD display and to be transferred to the appropriate GC display. Alternatively, if CD does issue pushback clearances on a routine basis, then the first CLEAR action will change the prefix character for the flight in the CD ACID list to a "#" sign. This indicates that the aircraft's clearance has been read but that the pilot has not yet received pushback clearance. Once pushback clearance has been granted, Clearance Delivery will touch the appropriate flight number in the ACID List and then CLEAR for a second time. This will cause the CD display to be cleared of this flight and cause it to appear on the appropriate GC display.

Remove - This action will clear the Readout Area and have no other effect.

Cancel IFR - Clearance Delivery can change an IFR flight plan for a flight displayed in the Readout Area to a VFR flight by touching this control. When this action is taken the beacon code field will be cleared and a VFR beacon code assigned by the TFDP, will be displayed in its place.

By means of the ACID List, the Readout Area and the Quick Action Controls, Clearance Delivery can receive and issue flight plan clearances, issue pushback clearances if that is airport policy, and handoff processed flights to Ground Control. The remainder of the display has to do with airport status data, weather data, and communications with the TIPS computers by means of a keyboard. In the example display presentation, it is seen from the Status Area that runway 9-18 is closed and runways 33 and 36 are available for operations. In the Weather Area the local altimeter setting is 29.92 inches of mercury, the ceiling is 13,000 feet with broken clouds, the visibility is 12 miles, the temperature is 68 degrees, the dew point is 59 degrees, the wind is at 310 degrees at 18 knots with gusts to 30 knots and the local time is 12:36:34.

Associated with the CD keyboard are two areas on the display and one quick action control:

Preview Area

This area will allow the controller to preview his keyboard input before entry. A cursor will be used in this area to assist the controller in keeping track of his place when making flight plan amendments.

Computer Response Area (CRA)

This area will primarily be used to notify the controller of the acceptance or non-acceptance of manually entered data. When data is not accepted by the DP, a short description of the reason for rejection will be presented in this area. This area will also be used to call the controller's attention to what the computer considers to be significant flight data transactions and system problems.

Erase Quick Action Entry

The Computer Response Area will be cleared when this action is taken.

The keyboard permits CD to enter, amend, and cancel IFR flight plans and VFR (Extended Radar Service) flight data, to notify the system of aircraft delays and to modify the organization of his display. The FD position will have a similar keyboard capability. Since FD will be primarily concerned with the entry and amending of flight plans, the description of those particular keyboard input actions will be described in the FD section (Section 8.2.2.3). The remaining keyboard entry actions are:

Modify Display Organization

With this input, the controller can switch from one of the permitted organizations of the ACID List on his tabular display to another arrangement of the data in that list.

Cancel

With this keyboard input, the controller can delete a flight plan from the TIPS, NAS, and ARTS systems.

Hold

This keyboard input will be used to designate that a particular flight is being placed in a hold status or released from that status. The TFDP will in turn notify the ARTS and NAS systems of the delay status as necessary.

Transfer to Ground Control

The IOT sets up quick action flight data routes between CD and the active GC positions (see Section 8.2.2.1 - Runway/Controller Assignment). CD can use the keyboard to transfer flight data to ground control positions that are contrary to the IOT established routes.

In summary, CD would conduct his operation in the following manner with TIPS. When a pilot requests a clearance, CD would identify the flight in the ACID list, would request a flight plan readout, and would deliver the clearance to the pilot. Normally, after delivering the clearance, CD would transfer the flight to the GC TIPS display by means of a quick action entry. However, if CD routinely provides pushback clearances at the airport, this first quick action entry would only clear the flight plan from the CD display and mark the flight in the ACID list as having received flight plan clearance but not pushback clearance. Only after the flight had been given pushback clearance would CD transfer the flight to the CG display by means of a quick action entry.

8.2.2.3 Flight Data Position

Flight Data handles flight plan submissions and amendment requests. Today FD uses the FDEP keyboard/printer to handle these requests. FD also supports CD by taking the paper flight strips from the FDEP printer as they are printed out, inserting them into holders, and passing them to CD. With TIPS, this last task would be eliminated and the IFR data-oriented FDEP system would be replaced with a system capable of handling VFR as well as IFR operations.

Figure 8.2-3 shows an example display presentation for FD. The presentation is similar to that of CD (see Section 8.2.2.2) with the following exceptions:

Amendment Transfer List

When a flight plan amendment is requested from a GC or LC station, the amendment request will be displayed in this list area with the following format:

AA711 from GC1
AL905 from LC2

Entries will be added to the bottom of this list as received. An entry will not be deleted from this list until an amendment action has been successfully completed for that entry.

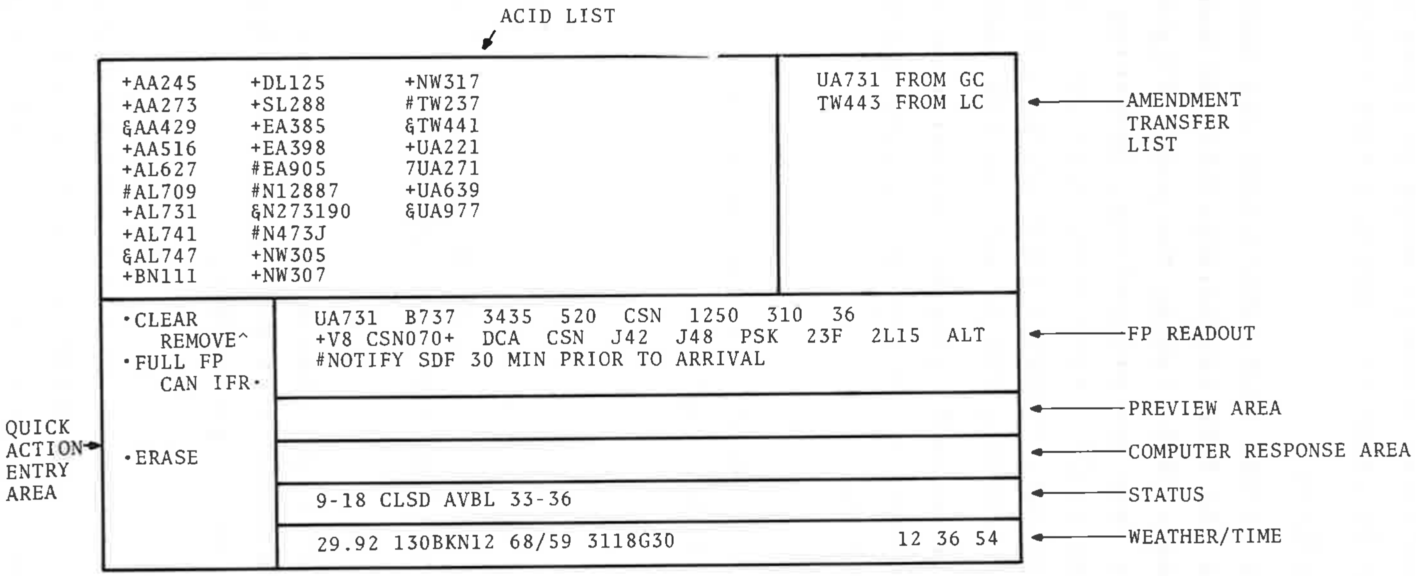
Read Quick Action Entry

FD can have the full flight plan of any entry in either the ACID List or Amendment Transfer List displayed in the Readout Area by touching the appropriate flight number.

Clear Quick Action Entry

Removal of an entry from the ACID List will take place on the FD display when CD has used the CLEAR on his display to transfer a flight to GC. CLEAR is an illegal action from the FD position.

The Amendment Transfer List permits the ground and local controllers in the cab to transfer a pilot's flight plan amendment



```
+AA245    +DL125     +NW317                      UA731 FROM GC
+AA273    +SL288     #TW237                      TW443 FROM LC
&AA429    +EA385     &TW441
+AA516    +EA398     +UA221
+AL627    #EA905     7UA271
#AL709    #N12887    +UA639
+AL731    &N273190   &UA977
+AL741    #N473J
&AL747    +NW305
+BN111    +NW307

•CLEAR        UA731  B737  3435  520  CSN  1250  310  36
  REMOVE^     +V8 CSN070+  DCA  CSN  J42  J48  PSK  23F  2L15  ALT
•FULL FP      #NOTIFY SDF 30 MIN PRIOR TO ARRIVAL
  CAN IFR•

•ERASE
              9-18 CLSD AVBL 33-36
              29.92 130BKN12 68/59 3118G30               12 36 54
```

FIGURE 8.2-3 EXAMPLE OF FLIGHT DATA DISPLAY PRESENTATION request to Flight Data by means of their quick action controls. In the example display presentation, Flight Data has received two such requests. The ground controller has requested an amendment for UA731 and the local controller has made a similar request for TW443. To handle such a request FD will first request the full flight plan in the Readout Area by touching the flight number in the Amendment Transfer List. This has been done in the example for UA731. FD will then have to find out from Ground Control the details of the amendment request. This can be accomplished in a number of ways. GC can instruct FD on the details either verbally or by means of a passed note, or GC can instruct the pilot initiating the request to switch to the CD/FD frequency and to give the details of the request directly.

To enter an amendment request, FD will use one of the following functions available on the TIPS keyboard:

Amend IFR Flight Plan

This keyboard action will provide the capability of amending one or more fields of an IFR flight plan. To amend an IFR flight plan, the full flight plan must first be displayed in the Readout Area. On selecting the IFR AM function key, the display cursor will automatically be positioned at the beginning of the "aircraft type" field of the displayed flight plan. The controller can then use the TAB control key to skip data fields that do not require amending. When the cursor is on the field to be amended, the controller will type in the amendment. The input will overwrite the displayed field data in the Readout Area. When the necessary fields have been modified, the controller will depress the "Enter" control key. When an "accept" message is received from the TFDP, the amended flight plan will be entered into the DP for processing. If a reject message is received, the reason for the rejection will be displayed in the Computer Response Area (CRA).

If the flight with the amended field had been "cleared as filed" (i.e., had a "+" prefix character in the ACID List), the prefix character would be automatically changed to a blank upon acceptance of the amended flight plan. The blank prefix character would indicate to the controller that the flight is no longer "cleared as filed". If the amendment action was taken for a flight in the Amendment Transfer List, then the receipt of the accept message would cause the flight number and amended fields to blink on the sender's display indicating that the amendment had been accepted.

Amend VFR Flight Data (Extended Radar Service)

This keyboard action will provide the capability to amend one or more fields of stored VFR flight data. The procedure for amending VFR flight data is similar to the IFR flight plan case except that the processing associated with the prefix character of the ACID List entry would be omitted.

In like manner, FD would use the following keyboard functions available on the TIPS keyboard to submit IFR flight plans and VFR flight data for clearance.

Enter IFR Flight Plan

To enter an IFR flight plan, the appropriate function key would be depressed and the following fields entered:

Flight identification
Aircraft data
Beacon code (optional)
Speed
Coordination fix
Coordination time
Assigned and/or requested altitude
Route
Remarks (optional)

The acceptance or rejection of the flight plan would be displayed in the Computer Response Area. A rejection would be accompanied by the reason for the action.

Enter VFR Flight Data (Extended Radar Service)

To enter flight data for a VFR flight requesting Extended Radar Service, the ERS function key would be depressed and the following fields entered:

Flight identification
Aircraft data
Beacon code (optional)
Coordination fix (or 3-digit heading)
Coordination time (optional)
Altitude

Once again, an acceptance or rejection message would be displayed, and rejection messages would be accompanied by an explanation of the action.

When FD requires the flight plan of a flight whose ACID was not currently on display, he could use the following keyboard function:

Flight Plan Readout

This keyboard action will cause a search of the TIPS computers, the DP and TFDP, and the parent NAS computer for the requested flight plan. If the flight plan is found, it will be displayed to the controller; and if it is not found, a message to that effect will be displayed in the Computer Response Area.

The flight plan submission, amendment, and request keyboard functions are the ones that will be of most concern to FD. However, FD would also have the additional keyboard functions described for CD in Section 8.2.2.2, such as the ability to cancel flight plans.

In summary, TIPS would provide FD with a display presentation similar to the one for CD, except that it would contain an Amendment Transfer List. This list would contain those flights for which other control positions had requested flight plan amendment assistance from FD. FD would service these amendment requests as well as submit and cancel both IFR flight plans and Extended Radar Service VFR flight data by means of the TIPS keyboard. FD would also be able to enter new or modified weather and status information into TIPS for general distribution by means of the TIPS keyboard.

8.2.2.4 Ground Control Position

Ground Control's operational tasks are varied but tend to include:

Assignment of departure runway
Assignment of taxiway route
Sequencing traffic

Monitoring traffic to assure that (1) route assignments are being followed, (2) no aircraft under his control blunders onto an active runway, (3) intersection conflicts are resolved, (4) no vehicle requesting Ground Control service is unduly delayed, and (5) conflicts between vehicles under his control and those of either Local Control or another ground controller are resolved.

To perform these tasks, GC uses the cab window to determine current traffic status, uses the VHF voice channel to communicate with vehicle operators, and uses the flight strip as a file of critical traffic management information to which he can refer. Specifically the flight strip provides:

a. Flight data on each aircraft for which the controller is responsible (e.g., weight class and coordination fix which are used to make departure runway assignments).

b. A scratch pad for flight data amendments and pertinent traffic control information (e.g., the departure runway selected and an associated notation indicating that the pilot was given the departure runway assignment).

c. A means for the controller to organize and reorganize his flight strips (i.e., the order of his flight strips) to reflect the on-going traffic situation and its changes. This procedure is used by controllers as an aid in correlating flight numbers with actual aircraft for communication and traffic monitoring purposes.

d. A vehicle for coordination between controllers. The strip contains traffic management information pertinent to each controller and its passage from one controller to the next represents a positive handoff.

GC tends to use his flight data on a quick-look basis, particularly during peak traffic periods at the busier airports. During busy periods GC will devote his attention to monitoring the traffic situation through the window and to maintaining his surveillance even while communicating with the vehicle operators. GC will only divert his attention to matters inside the cab to refer to or update his flight data.

Today, Ground Control's quick-look data base consists of paper flight strips in holders stacked in a tray at his station. GC maintains this data base with a pencil and by physically manipulating the strips in the tray and at handoff. With TIPS, the paper flight strip will become electronic and the pencil and physical manipulation of the strips will be replaced by a quick-action entry device and a keyboard. Figure 8.2-4 shows an example of a display presentation for GC. The format and operation of the Readout, Preview, Computer Response, Status, and Weather Areas are similar to those described for the CD display in Section 8.2.2.2. The remainder of the display presentation consists of:

Arrival List

The Arrival List Area will contain 10 or more flight entries. Scrolling or paging will be used to permit more flights to be accommodated. Each flight entry in the list will contain one line of flight data. The displayed flight data will contain such data as:

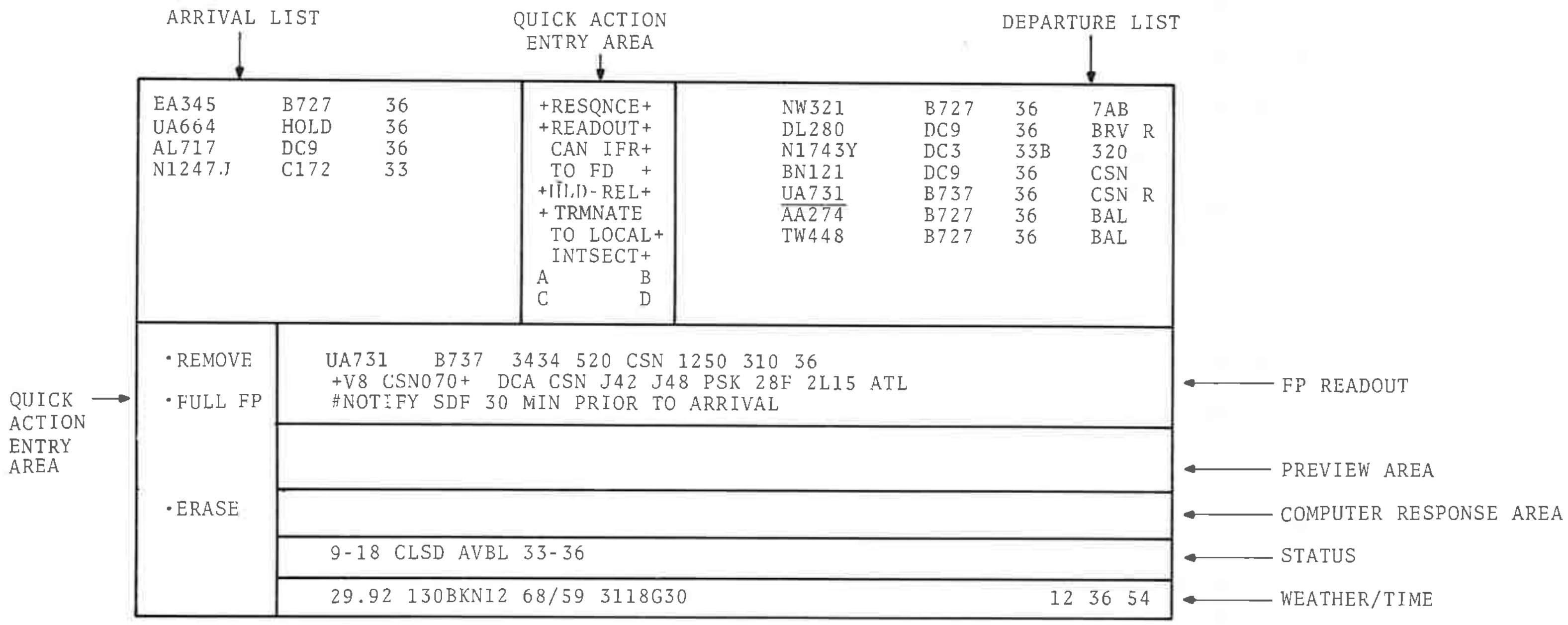
Aircraft identity
Aircraft type
Assigned runway
Remarks indicator - The character "R" indicates that the flight plan contains a remarks field; otherwise, the indicator is a blank.

Arrivals will be added to this list on handoff from LC or another GC. GC will be able to delete flights from this list by means of his quick action data entry device.

GC will have a number of keyboard selectable schemes available for organizing the flight numbers in the Arrival List. Examples of these organization schemes are:

New entries added to the bottom of the list in the order received.

The flight numbers sorted into sublists based on their arrival runway numbers and then each new entry added to the bottom of the appropriate sublist.



NOTE: "+" by upper quick action area need not actually appear on the display. It is used to designate thatthe quick action may be taken onthe designated list.

FIGURE 8.2-4. EXAMPLE OF GROUND CONTROL DISPLAY PRESENTATION

The flight numbers sorted alphanumerically.

The flight numbers sorted into sublists based on their arrival runway numbers and then each sublist sorted alphanumerically.

Departure List

The Departure List will be similar in capacity, data displayed, and organization to the Arrival List. The list will display 10 or more departures and will have a scrolling or paging feature. The flight data displayed will contain:

Aircraft identity
Aircraft type
Assigned runway
Coordination fix (or heading for VFR flights)
Remarks indicator

Departures will be added to the list by CD or another GC position. Departures will be deleted at handoff by means of the quick action data entry device. Finally, there will be two list organization schemes available in addition to the schemes available for the Arrival List.

These two schemes are:

The flight numbers sorted chronologically by planned departure time

The flight numbers sorted into sublists based on departure runway number and then each sublist sorted chronologically by planned departure time.

In the example of a display presentation, GC has selected to have new entries added to the bottom of both the Arrival and Departure Lists in the order received. The most recent entry in the Arrival List is N1247J, which is a Cessna 172 and has just landed on Runway 33. In the Departure List the most recent entry is TW448, which is a Boeing 727 that will be taking off from Runway 36, and flying over coordination fix BAL.

To manipulate the data in the Arrival and Departure Lists, GC will have a Quick Action Entry Area set up between these lists. The quick action controls include:

Resequence Action (RESQNCE)

This action will permit the reordering of flights in the Arrival and Departure Lists. The sequence for reordering a flight in the list would be to touch the flight number that is to be resequenced, then to touch the flight number below which the resequenced flight is to be located, and finally to touch the resequence function. To move a flight to the top of the list, the flight number to be resequenced would be touched twice followed by the resequence command. The resequence action will also cause the remainder of the list to be modified so that blank lines would only appear at the end of the list.

Readout Action

This action will result in a full flight plan being displayed in the Readout Area for the requested flight.

Cancel IFR Action (CANIFR)

This action taken for a departure flight will result in the IFR beacon code field being purged from the TIPS' computers.

To Flight Data Action (TO FD)

This action will permit GC to transfer a flight under his control requiring a flight plan amendment to FD for modification. When the transfer is made, the ACID of the transferred flight plan will be underlined in the Departure List to indicate that a modification is pending. When the amendment has been completed by FD, this line under the ACID on the GC display will be removed and then the ACID will be blinked along with the amended fields in the flight plan displayed in the Readout Area. Clearing the amended flight plan Readout Area by means of the Remove quick action entry will terminate this blinking.

Hold/Release Action (HLD-REL)

When GC finds it necessary to hold an aircraft, GC could use this action to display the word "HOLD" in place of the runway designator for the flight that is being held. When the flight is released from its hold, GC would then take this action for a second time, which would cause the "HOLD" indication to be replaced with the flight's assigned runway.

Terminate Action (TRMNATE)

When GC completes his control responsibilities for an arrival by delivering it to its destination on the airport's surface, GC would use this action to delete the flight from his displays and the TIPS computers.

To Local Action (TO LOCL)

This action will cause the designated departure to be deleted from the GC display and to be added to the appropriate LC display.

Intersection Departure Action (A B C D)

When GC assigns an intersection takeoff, GC will use this action to notify the TIPS computers of the assignment and to display the assigned intersection designator (e.g., C) as the last character in the assigned runway field (e.g., 36C). Each airport will have at least four, site adapted intersection designators. In the example, the four designators are A through D.

From the example of a display presentation, Figure 8.2-4, it is seen that arrival UA664 is being held, that departure N1743Y will make an intersection takeoff from runway 33 at the B intersection, that UA731 has been sent to Flight Data for a flight plan modification and that GC has requested the full flight plan of UA731 to be displayed in the Readout Area. When the flight plan is modified, the amended fields will blink in the displayed flight plan. GC will then notify UA731 of the acceptance of the amendment request and will terminate the blinking fields by means of the REMOVE quick action entry. The quick action entries associated with the Readout and Preview Areas are a subset of those available to CD and are described in Section 8.2.2.2.

GC will use his keyboard to:

Modify Display Organization

This keyboard action will provide the capability of selecting one of the available methods to organize the flight numbers in the Arrival and Departure Lists. The two lists can be independently organized.

Runway/Aircraft Reassignment

If GC wishes to assign a runway to a departure other than the one assigned by the TIPS computer, this keyboard action will permit GC to change the displayed runway assignment and to notify the TIPS computers of the change.

Transfer to Local Control

The IOT sets up "quick action" flight data routes between the active GC and LC positions (see Section 8.2.2.1 - Runway/Controller Assignment). GC can use his keyboard to transfer flight data to a Local Control position that is contrary to the IOT established route.

Transfer to Ground Control

This keyboard action will permit flight data to be transferred from one GC position to another.

Cancel Flight Plan

This keyboard action will permit GC to cancel a flight plan.

Hold

This keyboard action will permit GC to designate that a particular flight is being placed in a hold status or released from that status. The TFDP will in turn notify the ARTS and NAS systems of the delay as it is necessary.

In summary, TIPS will present to GC displayed lists of the arrivals and departures that are his current responsibility along with summary flight data on each flight, such as aircraft type and runway assignment. The summary flight data to be displayed will be facility selectable. To manage this flight data, GC will have a quick action data entry device and a keyboard. The following is a brief description of how GC would tend to use these new equipments in carrying out his routine traffic control functions. For departures, a flight would be added to the GC Departure List when it had been handed off by CD. When the pilot requests taxi instructions, GC will locate the aircraft out the window and then look in at the TIPS display to get the data necessary to select a taxiway route for the flight. First GC will verify that the computer generated runway assignment for the flight is valid. If it is not appropriate, GC can change the displayed runway assignment by a keyboard entry. If the pilot requests an intersection takeoff from the computer assigned runway, GC can make this change to the displayed runway assignment by a quick action entry. Once the correct departure runway is displayed, GC will determine the taxiway route to be assigned. GC will then assign the route and departure runway to the pilot. Today, route assignment and verification that the pilot has been issued the assigned departure runway are at times noted on the paper flight strips. This is done to avoid confusion in the first instance and to correct oversights by a form of book keeping in the second instance. With TIPS, GC would be expected to remember these facts (with the aid of a scratch pad), if they are of concern to him. TIPS does not plan to have a scratch pad capability and probably will not accommodate relatively uncommon or airport unique flight data notations or usage.

Continuing with departures, if a pilot requests a flight plan amendment from GC, GC can transfer the request to FD by means of a quick action entry. This quick action entry will also cause the flight number in the Departure List of the GC display to be underlined. This notation will act to keep GC aware of the unfulfilled request. When the TIPS computer accepts the amendment, GC will be automatically notified by the blinking of the associated flight number in the Departure List and of the amended fields in the flight plan displayed in the Readout Area. If it becomes necessary to hold a departure, GC can display the hold status of the flight by means of a quick action entry. If it becomes necessary to notify other ATC facilities of the delay, GC can do that by means of a keyboard input. To handoff a departure to LC, GC will again use one of the quick action entries. This action will cause the flight data to be transferred to the appropriate LC display and to the Departure List of the appropriate departure controller in the parent TRACON. Before leaving the Departure List, if GC notices that the sequence of flight numbers in this list are out of order for his purpose, he can reorder the flight numbers by use of a quick action entry.

Arrivals will be handled in a similar manner. A flight will be added to the Arrival List of the appropriate GC display when LC hands off the arrival. This usually occurs as the arrival clears the runway. When the pilot requests taxi instructions, GC will locate the aircraft on the field and assign a taxiway route to the pilot. TIPS displays the arrival runway used by each flight, so GC may interrupt his out-the-window surveillance to look at the display if he is having trouble locating the aircraft. TIPS does not display the airport destination for the arrivals, because that information is not readily available to the TIPS data base. If the airport destination of an arrival is not obvious to GC, he will request the information from the pilot and will then issue an appropriate taxiway route. As in the case of departures, GC will be expected to remember the airport destinations and the route assignments for the arrivals under his control. In brief, it is possible that GC will tend to handle the initial contact with an arrival without reference to the TIPS display unless it is to verify that he does have an electronic strip for the aircraft.

As with departures, GC will be able to display the hold status of arrivals and to resequence the flight numbers in the Arrival List to suit his needs. When arrival has reached its destination at the airport, GC will delete the flight from his display and from the TIPS data base by means of a quick action entry.

8.2.2.5 Local Control Position

The operational task for LC is to utilize the airport's runway to their operational capacities while maintaining the safety of the runway operation. To perform this task, LC uses an ARTS BRITE display for surveillance of airborne traffic, uses the cab window for surveillance of the runway traffic, uses the VHF voice channel for communication, and uses the flight strip as a file of critical traffic management information to which he can refer. Like GC, LC also tends to use his flight data on a quick look basis relative to surveillance out the window and of the ARTS

BRITE. However, unlike GC, LC requirements on his flight data are relatively simple.

In contrast to GC:

LC traffic seldom changes order with respect to one another resulting in less flight data manipulation required by LC in order to maintain the correlation between his flight data and the actual aircraft.

LC is usually only concerned with four aircraft in his operation regardless of the number of aircraft under his control: the arrival on the runway, the next arrival, the last departure, and the next departure.

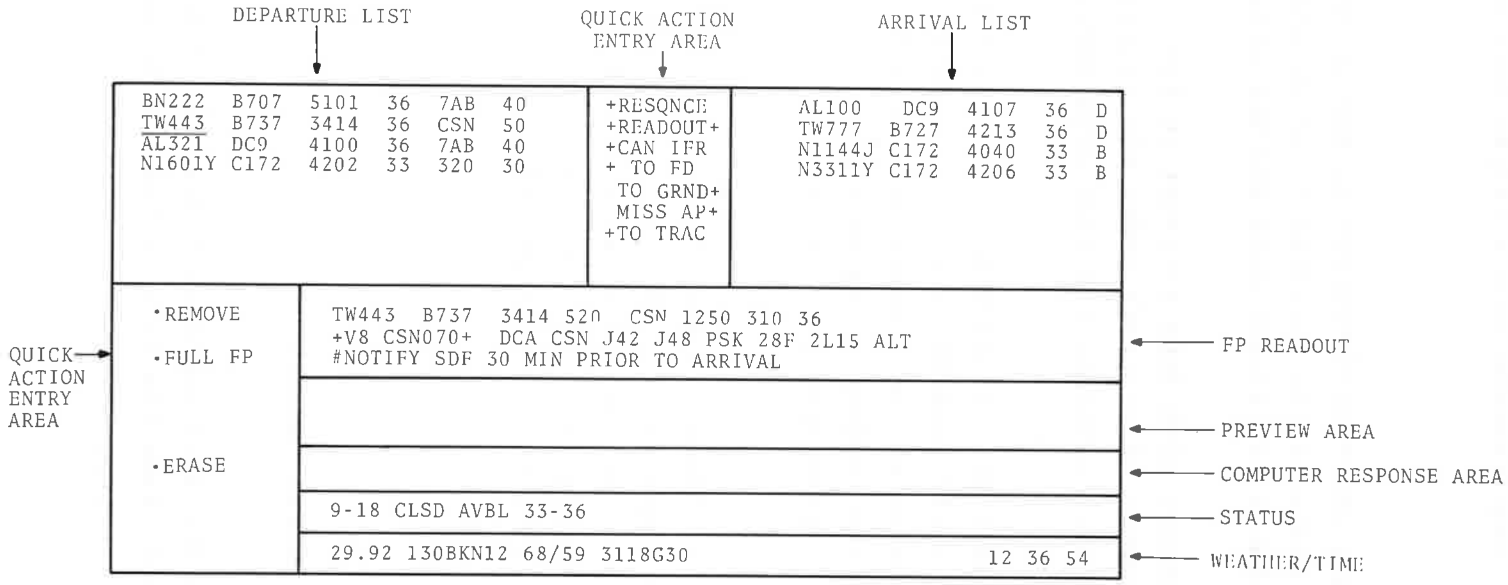
Figure 8.2-5 shows an example of a display presentation for LC. The format and operation of the Readout, Preview, Computer Response, Status, and Weather Areas on the tabular display are similar to those described for the CD display in Section 8.2.2.2. The remainder of the display presentation consists of:

<u>Arrival List</u>

The LC Arrival List will be similar to the GC Arrival List in capacity and in the schemes available for organizing the list, described in Section 8.2.2.4. The one line of summary flight data displayed per flight will be selectable by the facility. One example of what summary flight data could be displayed is:

Aircraft identify
Aircraft type
Beacon code
Assigned runway
Approach type (entered by the TRACON)
Remarks indicator

Arrivals will be added to the list on handoff from the TRACON. LC will be able to delete flights from the list at handoff by means of the quick action data entry device.



NOTE: "+" by upper quick action area need not actually appear on the display. It is used to designate that the quick action may be taken on the designated list.

FIGURE 8.2-5. EXAMPLE OF LOCAL CONTROL DISPLAY PRESENTATION

Departure List

The LC Departure List will also be similar to the GC Departure List in capacity and in the schemes available for organizing the list. An example of what summary flight data a tower might choose to have displayed on this list for each flight is:

Aircraft identity
Aircraft type
Beacon code
Assigned runway
Coordination fix (or heading for VFR flights)
Altitude at coordination fix
Remarks indicator

This is the summary flight data shown in the example of a display presentation, Figure 8.2-5. Departures will be added to the list on handoff from GC and deleted from the list on handoff to the TRACON.

In the example of a display presentation, LC has selected to have flights in the Arrival and Departure Lists sorted into sublists by runway and to have each new entry added to the bottom of the appropriate sublist. In the Departure List, AL321 is the most recent entry into the runway 36 sublist. AL321 is a DC9, has been assigned beacon code 4100, will depart from runway 36, and will pass over coordination fix 7AB at 4000 feet. TW777 is the most recent entry into the runway 36 arrival sublist. It is a Boeing 727, has been assigned beacon code 4213, will land on runway 36, and was assigned approach D to that runway.

Like GC, LC has a Quick Action Entry Area located between the Arrival and Departure List Areas, which will be used to manipulate the data in those lists. The following quick action functions are similar to those described for GC in Section 8.2.2.4, except for the noted exception:

Resequence - exception, since arrival flights are sequenced by the TRACON, the Resequence action will only be legal for departure flights.

Readout
To Flight Data
Cancel IFR

The remaining quick action functions associated with the Arrival and Departure Lists are:

To Ground Action (TO GRND)

At handoff, this quick action will cause the designated arrival to be deleted from the LC display and to be added to the Arrival List of the appropriate GC display.

Missed Approach Action (MISS AP)

When a missed approach occurs, LC will use this quick action to delete the flight from his display and to transfer it to the TRACON for resequencing. When the flight is resequenced by the TRACON, the arrival flight data will be reentered into the LC Arrival List.

To TRACON Action (TO TRAC)

At handoff, this quick action will cause the designated departure to be deleted from the LC display and will notify the central TIPS computer of the handoff.

The quick action functions associated with the Readout and Preview Areas are a subset of those available to CD and are described in Section 8.2.2.2.

LC will have keyboard functions similar to those described for GC in Section 8.2.2.4. Specifically:

modify display organization
transfer to ground control
cancel flight plan
hold

In brief, TIPS will present to LC a display containing summary flight data on the flights that are his current responsibility and will provide LC with a quick action data entry device and a keyboard with which to manage this flight data. The following is a brief description of how LC would tend to use this new equipment in carrying out his routine runway management functions. For arrivals, a flight will be added to the Arrival List when it has been handed off by Approach Control in the TRACON. When the pilot checks in for landing instructions, LC will check the flight on the display to verify the runway assignment and to determine how the aircraft should be handled (e.g., aircraft type and weight class). He will then issue the landing instructions. If a missed approach occurs, LC can return the flight to the TRACON for re-sequencing by a quick action entry. If a missed approach does not occur and the aircraft lands and rolls out, LC will hand off the arrival to GC by means of a quick action entry when the aircraft turns off the runway.

For departures, a flight will be added to LC display when it has been handed off by GC. When the pilot checks in for take-off instructions, LC will check the flight on the display to verify the runway assignment. When the aircraft is the next to takeoff, LC will again check the display to determine how the departure should be handled. This is done by noting the departure's coordination fix or heading assignment if it is a VFR flight, and its aircraft type and weight class. LC will then issue his take-off instructions to the pilot. At some point after lift-off, LC will hand the departure over to the appropriate departure controller in the TRACON by means of a quick action entry.

8.2.2.6 Combined Positions

The input/output terminal (IOT) in the tower cab controls the type of controller position that is to be operated at each of the display and data entry units in the cab. The IOT can be used to combine control positions, e.g., CD/GC; to split positions, e.g., GC1 and GC2; and to shift positions from one display and data entry unit to another. The keyboards at the various TIPS display and data entry units in the cab will have their formats semi-permanently fixed. If a keyboard is used operationally for more than one control position, e.g., GC during the day and CD/GC at night, the keyboard will contain the sum of the data entry functions required by those positions. On the other hand, the computer generated formats of the display presentation and of the quick action data entry device (touch sensitive display face mechanization) will not have this limitation. Regardless of the number of positions for which a particular unit is used operationally, the formats of the display presentation and quick action data entry device will contain only those features associated with its currently defined position. The following are examples of these computer generated formats for some of the combined positions that will be available.

Combined Clearance Delivery/Flight Data Position

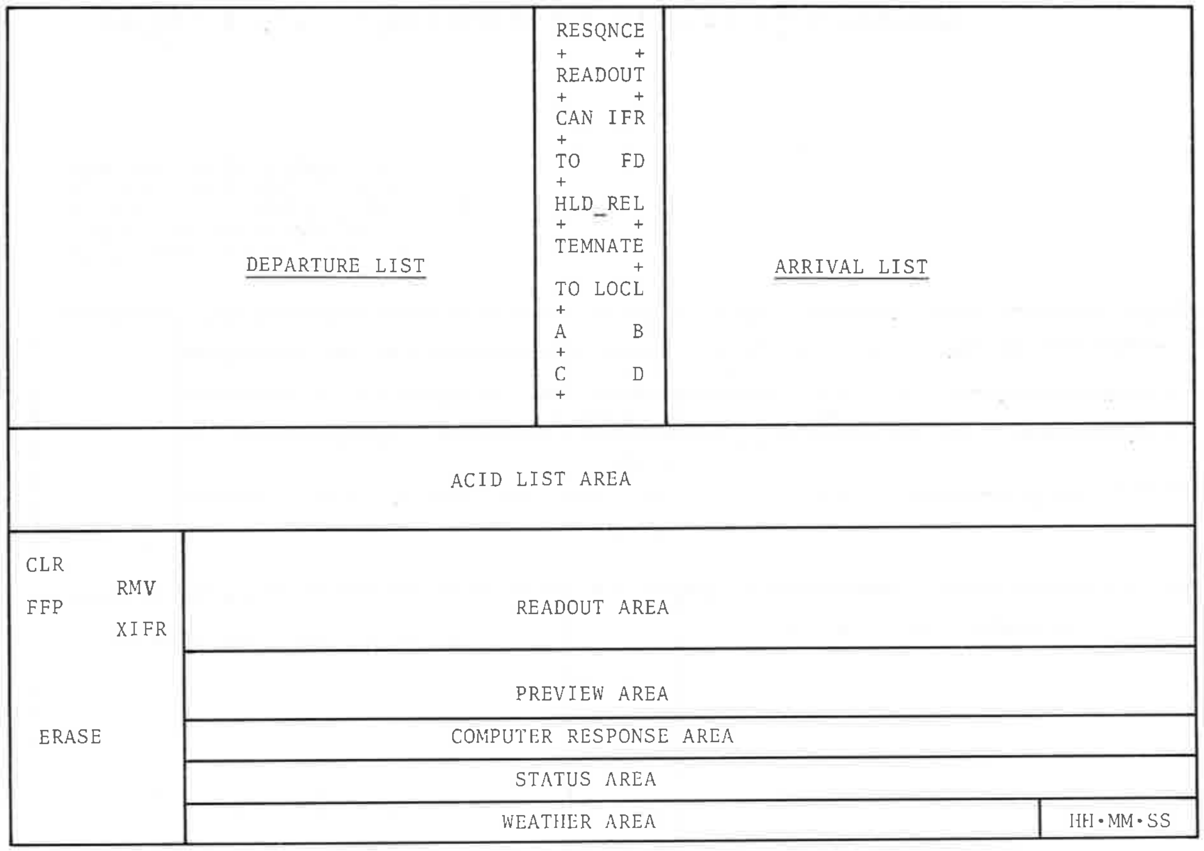
When a console is designated by the IOT to be a combined CD/FD position, the display presentation will be the same as for the FD position, Figure 8.2-3. The quick action functions will operate as they were described for CD, Section 8.2.2.2, except that the READOUT action will also apply to entries in the Amendment Transfer List.

Combined Clearance Delivery/Ground Control Position

When a console is designated by the IOT as a combined CD/GC position, the display presentation will contain both the ACID List found on the CD display and the Arrival and Departure Lists associated with the GC presentation. Figure 8.2-6 shows how the combined presentation would tend to appear. The number of display lines alloted to the Arrival/Departure Lists and to the ACID list will be an input parameter. The quick actions available at the combined position will be a composite of those available at the two individual positions.

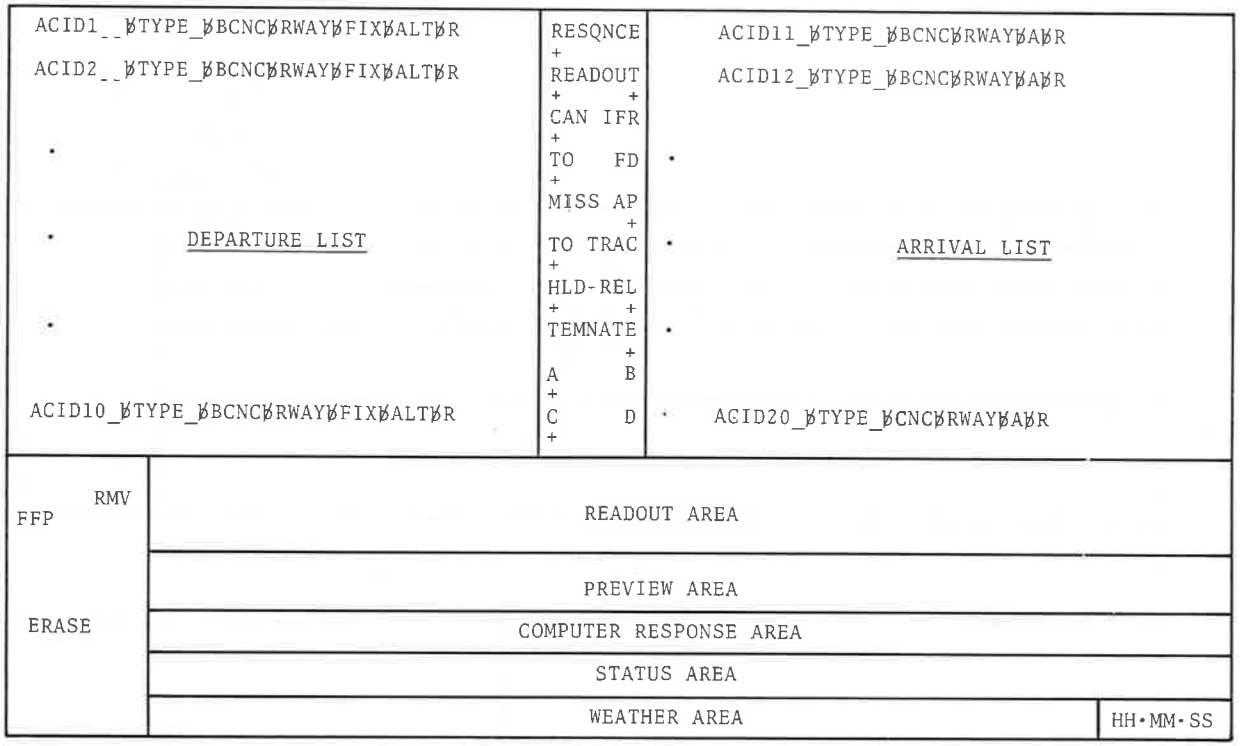
Combined Ground Control/Local Control Position

The display presentation for the combined GC/LC position will be the same as for the LC position, Figure 8.2-7. The quick actions available at the combined position will essentially be a composite of the actions available at the individual GC and LC positions.



NOTE: "+" by upper quick action area need not actually appear on the display. It is used to designate that the quick action may be taken on that designated list.

FIGURE 8.2-6. COMBINED CD/GC DISPLAY PRESENTATION



NOTE: "+" by upper quick action area need not actually appear on the display. It is used to designate that the quick action may be taken on the designated list.

FIGURE 8.2-7. COMBINED GC/LC DISPLAY PRESENTATION

8.2.3 Tower Cab Data Retention Subsystem

After flight strips are used in the tower cab, they are kept for two purposes. They provide:

1. Controllers with a means to reconstruct the operational details surrounding an incident to which they might testify.
2. FAA statisticians with data on traffic demand and ATC system performance.

The details of how TIPS would implement these flight strip functions have yet to be worked out. However, the TIPS concept seems to lend itself to data recording and collection. The TIPS computer will be aware of current information, such as:

airport status
weather
operational traffic pattern
traffic delays in effect by controller position
traffic under control of each position

In addition, the TIPS computers will be notified by controller input of changes in each of these categories. With this data and the ability to log the times of the various controller actions, TIPS seems particularly well suited to take on the data logging function. It is possible that a data retention subsystem based on TIPS could be superior to the current one based on the flight strip in the following areas:

Data recorded could be more extensive and accurate

Data could be formatted for easier compilation by the FAA statistician

Recorded data would be more difficult to alter after the fact and could perhaps be admissable as evidence as are control tower communications tapes

Data recording could require less involvement on the part of controllers.

8.2.4 TIPS Data Processing

8.2.4.1 Processing Requirements

The basic function of TIPS is to assemble, maintain, and provide access to the flight data information pertinent to the operations of a terminal area. As part of this activity, TIPS will have to support both data entry and display devices and input/output interfaces. The devices will be located for the most part in the tower cab and the TRACON, while the interfaces will support communications with other facilities, such as the ARTS computer and the ARTCC computer, and with remote sources such as adjacent terminals or possible Flight Service Stations.

A major part of the total amount of processing to be done on TIPS is that required to support the data entry and display activities in the tower cab. On the basis of an analysis of a number of different computer configurations, the tower cab processing was separated from the rest and each part assigned to a different, new computer complex. This arrangement was shown in the study to be more effective, economically and operationally, than the use of the ARTS computer alone or the use of display processors driven by the ARTS computer. The requirements document[5] will describe the TIPS data processing in terms of such a configuration; it is reasonable to do the same thing here.

8.2.4.1.1 Terminal Flight Data Processing

The function of the Terminal Flight Data Processor (TFDP) to be located in the TRACON is to store and maintain the Flight Data Base for the terminal area. Flight data will be assembled by the TFDP from messages sent to it from the ARTCC, ARTS, the TRACON Display Processor (TRDP) and the Tower Display Processor (TDP). Bulk stored flight plans will be sent the TRDP from the ARTCC in the same way they are now sent to ARTS and FDEP. The terminal processor will distribute the flight plans to the tower, TRACON or ARTCC as appropriate, depending on the source of data, type of flight, and intent (arrival or departure). In addition, specific flight plans are available on demand.

In order to carry out this function, the TFDP operational program will be organized in the conventional modular fashion, with a simple executive routine providing system monitoring and control, managing the interrupt system and scheduling tasks according to priority. It will provide the elementary file control procedures needed to support the data base management operations. The executive will also perform normal startup and shutdown functions as well as startovers associated with system configuration changes or recovery from failure.

The principal operational program in the TFDP subsystem is the input message processing routine; it handles the messages from the ARTCC, ARTS and the Tower Display Subsystem (TDS) and the TRACON Display Subsystem (TRDS). There are four classes of messages which can be passed within TIPS; these have been described for the most part in terms of their operational use in the tower cab and are summarized in a set of tables here to show how they are treated by the data processing subsystem. The four categories are:

Flight Data Messages (see Table 8.2-1)
Supplementary (Weather and Status) Data Messages (see Table 8.2-2)
Tracking and Control Messages (see Table 8.2-3)
Test and Response Messages (see Table 8.2-4)

The input message processor is responsible for checking each message for certain types of errors, sending the proper response message and carrying out the indicated message processing. Several messages are received by the TFDP and are re-transmitted to other computers directly, without any intermediate processing: TRACK UPDATE (TU), STRIP REQUEST (SR), MESSAGE REQUESTED (MR), and TEST DEVICE (TD).

Flight data distribution involves transmittal of data to ARTS and to the DPS according to a time criterion. Flight plans for departing aircraft are sent to ARTS and the TRDS when the flight is activated and for arrivals according to estimated time at entry fix. Flight data is sent to the TDS in time to support tower operations.

TABLE 8.2-1 FLIGHT DATA MESSAGES

Message	Description	Requirements	Source
FLIGHT PLAN (FP)	file proposed or active flight plan into data base	message type flight identification aircraft data beacon code speed coordination fix and time assigned or requested altitude route remarks	ARTCC, ARTS, or TIPS keyboard
AMENDMENT (AM)	modify, add, or delete previously filed flight plan data	message type flight identification field reference number amendment	ARTCC, ARTS, or TIPS keyboard
REMOVE STRIP (RS)	remove from core storage all flight data for a specific flight plan (IFR and VFR from TFDP data base and IFR from ARTCC)	message type flight identification	ARTS or TIPS keyboard
CANCEL (CX)	remove flight data from TFDP data base	message type flight identification	ARTCC

TABLE 8.2-1 FLIGHT DATA MESSAGES (Cont.)

Message	Description	Requirements	Source
REQUEST FLIGHT PLAN (RF)	request for flight plan data on specific flight	message type flight identification location identification	ARTS or TIPS keyboard
DEPARTURE DELAY (DD)	adjust estimated departure time	message type airport identifier delay value	ARTS or TIPS keyboard
HOLD (HM)	initiate or modify hold action; places or removes a flight from hold status	message type flight identification hold data	ARTS or TIPS keyboard
PROGRESS REPORT (PR)	update status of an active flight, or release a flight from hold	message type flight identification progress report data	ARTS

TABLE 8.2-1 FLIGHT DATA MESSAGES (Cont.)

Message	Description	Requirements	Source
PARAMETER CONTROL (PC)	adjust time at which flight data is supplied to TIPS display processors	message type parameter ID transmission time	TIPS display
RESTORE TIPS DATA BASE (RG)	TFDP re-transmits all currently applicable flight data to requested source	message type location identifier	TIPS display
RESTORE ARTS III BASE (RB)	restore all current flight plan data to ARTS	message type location identifier	ARTS

TABLE 8.2-2 SUPPLEMENTARY DATA MESSAGES

Message	Description	Requirements	Source
WEATHER (WX)	update local weather in TFDP and ARTCC data bases	message type location identifier weather data entrance time* weather data	TIPS display processor
ALTIMETER SETTING (AS)	update local barometric air pressure in TFDP and ARTCC data bases	message type altimeter data entrance time location identifier altimeter setting	TIPS display processor
STATUS (ST)	update status information in TFDP data base	message type location identifier active runways status data	TIPS display processor
GENERAL INFORMATION	enters text to be displayed or printed at designated positions	message type output routing remarks	ARTS or TIPS display processor

* time of observation

TABLE 8.2-3 TRACKING AND CONTROL MESSAGES

Message	Description	Requirements	Source
DEPARTURE (DM)	notify TIPS and ARTCC computers that flight has departed, transmit flight plan to adjacent facility	message type flight identification coordination time	ARTS
TERMINATE BEACON (TB)	track has been dropped, discrete beacon code is available for reassignment	message time flight identification	ARTS
TERMINAL TRANSFER (TT)	identifies controller position responsible for particular flight	message type flight identification originating position destination position	TIPS display processor

TABLE 8.2-3 TRACKING AND CONTROL MESSAGES (Cont.)

Message	Description	Requirements	Source
INITIATE TRANSFER (TI)	initiates the transfer of control of a flight between ARTCC and ARTS or ARTS and tower controller	message type output routing flight identification track coordinates and velocity runway assignment	ARTCC or ARTS
ACCEPT TRANSFER (TA)	completes the transfer of control of a flight	message type output routing flight identification	ARTCC or ARTS

TABLE 8.2-4 TEST AND RESPONSE MESSAGES

Message	Description	Requirements	Source
ACCEPT (DA or AA)	sending computer has received referent message without any identifiable problems, successful transmition between TFDP and interfacing computer	message type flight identification referent message source	DA sent to or from ARTCC, ARTS or TIPS display processor AA received from ARTCC, or sent to ARTS
RETRANSMIT (DX)	retransmit message due to LRC, parity, or EOM error	message type referent message source	sent to or received from ARTCC, ARTS or TIPS display processor
REJECT (DR or RR)	reject message due to identifiable error (not DX error) RR specifies reason for reject DR does not specify	message type flight identification referent message source data	DR sent to or received from ARTCC or ARTS RR received from ARTCC or TIPS display processor, or sent to ARTS or TIPS display processor
DATA TEST (DT)	acceptable data successfully transmitted	message type referent message source remarks	sent or received from ARTCC, ARTS, or TIPS display processor
TEST DATA (TR)	tests each intercomputer communication channel	message type output routing remarks	transmitted and received by TFDP

The TFDP operational program will also have the capability of computing runway assignments for both departing and arriving flights. Obviously, this function is used only when multiple runways are in use and only when multiple runways are not assigned by some other means, as they normally are to arrivals by the ARTS controller.

Beacon code assignments will be requested of the ARTCC or ARTS by the TFDP program whenever they are needed, for instance, a tower or VFR en-route flight.

8.2.4.1.2 Tower Display Processing

The Tower Display Subsystem (TDS) consists of display and data entry equipment for each controller position and a processor or controller to drive them. The processing capability to provide the services described in earlier sections of this paper must be present in some form, divided among the processor/controller and the displays. Although the discussion below is, for convenience, in terms of a relatively powerful display processor driving relatively simple displays, it is not meant to discriminate against other configurations, such as those with "smart" terminals, which are specifically allowed by the engineering requirements.

The TDS operational program again, will be, of conventional, modular design, with an executive routine for monitoring and control purposes. The functions to be performed are, as might be expected: maintain the displays, process operator inputs, and interface with the TFDP.

Maintenance of displays means both refresh if necessary, and supply updates to individual positions, each of which has different requirements. There will be some common tasks, however, such as providing a preview area for input messages, displaying current weather and status information, responding to operator actions and displaying complete flight plans when requested. The major portion of each display presentation, as illustrated above, is the set of tabular lists used by a particular controller, lists of arrivals or departures, queues awaiting clearance, etc..The operator must, moreover, be able to manipulate these lists, adding and deleting flights and rearranging the order of entries.

The processing of operator inputs involves recognition of operator action and selection of proper response. There are two classes of actions: those local to the TDS and those requiring an intercomputer message. Examples of the former are the list rearrangements already mentioned and handoffs between positions, which require changes on the displays at both positions involved. Intercomputer messages must be recognized by type and formatted for transmittal to the TFDP.

Interfacing with the TFDP requires that a communication protocol be established and followed, and that operator input messages be properly relayed and responses received. Table 8.2-5 lists the message types which the TDS may be called upon to relay to the TFDP, while Table 8.2-6 lists those that flow in the other direction. These two lists are subsets of the complete set given earlier.

There will be available in the tower an input-output terminal (IOT) which will allow supervisory messages to be entered into the Tower Display Subsystem. These messages will be of two types: system control, such as STARTUP, and operational control, such as RECONFIGURE. A list of the messages of the second type is given in Table 8.2-7.

8.2.4.1.3 TRACON Display Processing

The TRACON Display Subsystem (TRDS) is similar to the Tower Display System just described. Since the two are functionally nearly the same, they may be expected to use the same types of processors and displays and a great deal of common software. The TRDS will have a larger number of displays and keyboards to service but they will, in general, be of only two types. The arrival controller and the departure controller. Since the TRACON Display Processor will be located near the TFDP and its peripherals, none was specified for the TRDP. In particular, no IOT is required since supervisory functions will be done through the IOT at the TFDP.

8.2.4.2 Processing Configurations

As has been implied in the previous section, the configuration of processors which is recommended for use in TIPS is one which

TABLE 8.2-5 MESSAGES FROM TDS TO TFDP

MESSAGES	DESCRIPTION
Flight Plan (FP)	files a proposed or active flight plan in storage
Amendment (AM)	modifies, adds, or deletes previously filed flight plan data
Request Flight Plan (RF)	requests printing of flight plan which is not available in local storage
Remove Strip (RS)	removes from storage all flight data for a specified flight plan
Terminal Transfer (TT)	transfers control of a flight from one control position to another
Departure Delay (DD)	notifies TFDP of delays affecting the processing of departure flights
Parameter Control (PC)	allows for modification of system parameters: TFDP ACID Transfer Time Parameter, TFDP Flight Plan Transfer Time Parameter
Status Message (ST)	allows for entry of system status data for presentation on tower display

TABLE 8.2-5 MESSAGES FROM TDS TO TFDP
(continued)

MESSAGE	DESCRIPTION
Altimeter Setting (AS)	updates altimeter data for selected reporting stations
General Information (GI)	allows for routing general data to specified destination
Hold (HM)	flight is placed in terminal area hold status or released from hold status
Restore Data Base (RG)	initiates recovery of DP data base
Accept (DA)	input message has passed all computer acceptance tests
Re-transmit (DX)	illegal LRC, parity, or EOM detected, retransmit message
Reject (RR)	input message can not be corrected or system can not handle the message
Test Data (TR)	verifies the proper operation of the communications channel between TDS and TFDP

TABLE 8.2-5 MESSAGES FROM TDS TO TFDP
(continued)

MESSAGES	DESCRIPTION
Data Test (DT)	response to TR message verifying acceptance checks on communications channel
Weather Message (WX)	allows for entry of local weather data for presentation on tower displays.

TABLE 8.2-6 MESSAGES FROM TFDP TO TDS

MESSAGE	DESCRIPTION
Flight Plan (FP)	files a proposed or active flight plan in storage
Amendment (AM)	modifies, adds, or deletes previously filed flight plan data
Cancel (CX)	cancel a flight which was previously transferred to TDS
Stored Flight Plan (SF)	notifies TDS of departing flight usually 10 minutes before proposed departure
Terminal Transfer (TT)	transfers control of a flight from one control position to another
General Information (GI)	disseminates general information from ARTS or ARTCC
Departure (DM)	notifies TDS that a flight has departed and tracking has begun
Accept (DA)	input message has passed all computer acceptance tests

TABLE 8.2-6 MESSAGES FROM TFDP TO TDS
(continued)

MESSAGE	DESCRIPTION
Re-transmit (DX)	illegal LRC, parity, or EOM detected, retransmit message
Reject (RR)	input message can not be corrected, or system can not handle the message
Data Test (DT)	response to TR message verifying acceptance checks on communication channel
Test Data (TR)	verifies the proper operation of the communications channel between TDS and TFDP

TABLE 8.2-7 SUPERVISORY MESSAGES

MESSAGE	DESCRIPTION
Runway/Controller Reassignment	alters the assignment of tower controllers to active runways
Parameter Control	allows for modification of system paramenters: TFDP ACID Transfer Time Parameter, TFDP Flight Plan Transfer Time Parameter
Reconfiguration	allows combining tower positions; allows separating tower positions; allows transfer of functions from one position to another
Restore Data Base	initiates recovery of DP data base
Modify Input Eligibility	allows for expanding the repertoire of keyboard actions at GS and LC
General Information	allows for routing general data to ARTS or ARTCC
Departure Delay	notifies TFDP of delays affecting the processing of departure flights
Enter Weather Data	allows for entry of local weather data for presentation on tower displays

TABLE 8.2-7 SUPERVISORY MESSAGES
(continued)

MESSAGE	DESCRIPTION
Enter Status Data	allows for entry of system status data for presentation on tower displays
Communications Test	manually initiates a test of the DP/TFDP communications interface

makes use of two new computers of conventional design, purchased off-the-shelf. One would be a mini- or microcomputer of modest capability for the TRACON processing, while the other would be either a small mini- or microcomputer driving limited-capability displays, or fairly complex programmable controller driving "smart" display terminals. These processors and their peripherals will make only modest demands for space on the TRACON and Tower Cab.

8.2.4.3 Prototype System Processors

The Engineering Requirements[5], for the TIPS prototype system spell out in some detail the processors to be used. The TRDP processor is described in general terms as having about 16K to 32K sixteen bit words of memory, a direct memory access (DMA) capability, a priority interrupt system of at least eight levels and communications controllers for four 2400 bps full duplex, synchronous interfaces. The required peripherals are an input/output terminal, a disk unit to hold the flight data base, a program storage unit, such as a cassette, and a line printer. Response time requirements are given as less than 1/2 second with probability 0.9 and less than 1 second with probability 0.999 when flight plans are being received at the rate of one per second from ARTS and one per second from each TIPS display processor (number not specified).

Except for the implicit requirement that the processor be able to handle the job, there are no others in the specification. Any of a number of minicomputers, of rather standard configuration and ordinary size would be expected to be acceptable.

The tasks performed by the Display Processors and display devices (or the controller and terminals) are not particularly demanding. Many small systems being manufactured today could be adapted to handle them.

Thus, the contractor who supplies the prototype system should have little difficulty meeting the requirements set for in these specifications.

8.3 TIPS INTERFACES

To date the TIPS Program has only conducted a cursory examination of the interface issues that will be involved in interfacing a production TIPS with other MSDP terminal area systems, such as TAGS and DABS. The Program has focused its resources on defining the interfaces of the prototype system with the current terminal area Air Traffic Control system-with emphasis on the NAS, ARTS and controller interfaces. These three interfaces have already been described in this section and a summary description for each of these interfaces is included in this subsection for convenience. The following discussions on the interface issues involved between TIPS and other MSDPs are based on the Program's early cursory examination of these interfaces as documented in references 4 and 6.

8.3.1 Controller Interface

TIPS will replace the entire FDEP/paper flight strip subsystem. Each controller will be provided with electronically displayed flight data on a tabular display and with two data entry devices - an ARTS III like keyboard and a "quick action" device. The display will present selected flight, weather, and status information of current interest to the controller. The display will also present full flight plan information in response to a controller request. For a detailed discussion of this interface see Section 8.2.

8.3.2 ARTS III Interface

The central computer in the TIPS prototype system (i.e., the TFDP) will interface with an ARTS III computer. The primary software modifications this interface will require of ARTS III are:

The presentation of summary flight data on the Plan View Displays on a quick look basis.

The output of available beacon codes to the TFDP on request.

The ability to operate in either a TIPS or a non TIPS mode.

This interface is discussed in more detail in Section 8.2.4.

8.3.3 NAS Interface

For TIPS, the interface of the TFDP with the NAS computer will be the second primary computer interface for both the prototype and production systems. The primary changes that the prototype model will require of the NAS software will be to permit:

Operations in either a TIPS/ARTS mode or, in the event of a system failure or shutdown, in a TIPS-only and an ARTS only mode.

The ARTCC to send full flight plan data to the TFDP when TIPS is operational.

The ARTCC to accept terminal area weather data from the TFDP when TIPS is operational.

This interface is discussed in more detail in Section 8.2.4.

8.3.4 Enhanced ARTS III Interface

The TIPS production system will interface with the enhanced ARTS III instead of the basic ARTS III system-at least for the initial deployment of 29 systems (see Section 8.5.2). ARTS III A will be designed with the capability to interface with TIPS. The present plan, concerning the design of the TIPS production unit, is to set up this interface so as to minimize the demands made by TIPS on the ARTS IIIA system. For more details on this interface see Section 8.2.4.

Part of the enhanced ARTS III package will be the Metering and Spacing function. To service this function the software of the TIPS production unit may be required to:

Provide flight plan information.

Accommodate the presentation of spacing and timing information on Local Control TIPS displays.

8.3.5 Automated Flight Service Station Interface

At present, flight service stations do not have a direct link with terminal ATC facilities, but rather support the entry of IFR flight data into the ARTCC data base. This flight data is then sent to the terminal ATC facilities as it is required. If the flight service station (FSS) automation effort provides a direct

FSS to terminal ATC facility data link, VFR flight data could be automatically input into the TIPS flight data base. This would relieve the terminal area controllers from having to enter it manually. Because of this possibility, the design of the TIPS production model should include a growth capability to support a direct data interface with the FSS.

8.3.6 Data Link Interface

Data Link may be the basis for many changes in terminal area operations and procedures. These changes have not yet been fully identified, but one obvious example would be the automation of Clearance Delivery for routine situations. The TIPS production system may be required to provide:

A direct interface with data link

The software to accommodate the changes in flight data processing requirements that will be levied on TIPS by the existence of an operational data link system within the terminal area.

8.3.7 MLS Interface

MLS is not expected to result in any changes to the flight data requirements levied on the TIPS production model.

8.3.8 TAGS Interface

Both TAGS and TIPS involve a major display and multiple data entry devices. Due to the relatively restricted space generally available in the tower cab for new displays and data entry devices, an analysis should be considered to determine the feasibility of having these two systems share pieces of equipment. However, such a feasibility analysis, involving the integration of TIPS with other new ATC systems currently under development by SRDS, has been beyond the resources of the TIPS program as explained in Section 8.3.

8.3.9 Automated Airport Weather Sensing Interface

Several on-going programs are proposing to increase the number and types of weather sensors to be installed on the surface of the airport and to automate the weather sensing function. The TIPS production system may be required to accept, process, and display automated local weather sensor data, and also data from satellite airports.

8.4 SYSTEM FAILURE

Tower Cab Operational Considerations

Operationally, two types of system failures are of interest to the cab -- the failure of a single display unit and the failure of a TIPS processor or communications link. The system will be designed so that the failure of a single display unit will not affect any other display unit in the cab. The back-up procedure in this case would be to use the Input/Output Terminal (IOT) to transfer the affected position to another display and data entry unit in the cab. If an unused unit is available, it can be used; or one of the active units can be made into a combined position with the affected controller sharing the other controller's unit.

Failure of a TIPS processor or communications link is a more serious situation, since all the TIPS units in the cab could be affected. If the facility is large enough to justify redundant equipment, the system will be fail-safe so that a single failure of this type will not affect the cab operation. At other facilities, the displays will be designed so that a static presentation of the last information displayed at the time of failure will remain for the controller's use to start their backup operation. If FDEP is available in the cab, the backup system could be the current cab flight data system. However, to reduce maintenance costs and to recover the space occupied by the FDEP equipment and flight strip trays in the typically space limited cab, this equipment would tend to be removed from a TIPS equipped tower cab once the controllers became familiar with the new system. Therefore, in the event of failure, Ground and Local Control would either use scratch pads or handwritten flight strips to maintain their flight data, depending on the extent and expected duration of the failure. Communication of flight data between the tower cab and other ATC facilities would be carried out by means of the interphone.

8.5 TIPS PROGRAM

8.5.1 Program Status/Schedule

The TIPS Program has completed the functional, engineering, and performance requirements for a prototype system. Based on these requirements, the Program is currently generating the system specification and the procurement package for the prototype system. The Program has funding through 1978 and has proposed the following schedule:

Award contract to build the prototype system in one year (i.e., summer of 1978)

Prototype system delivered for evaluation in another year (i.e., summer of 1979)

Complete the evaluation of the prototype system in one more year (i.e., summer of 1980)

Shortly thereafter, prepare specifications to support an Airway Facilities procurement of production systems for ARTS III locations

If warranted, prepare specifications to support a procurement of production systems for non-ARTS III equipped terminal areas.

8.5.2 Deployment Plan

The Program has not yet completed a deployment analysis for TIPS, but in accordance with the original AAT request for development activity, the Program sees the TIPS deployment as being the high activity ARTS III terminal areas. However, the Program believes that the TIPS design is applicable to terminal areas with all levels of traffic and numbers of control facilities.

For the basic deployment, the Program has assumed that it will include all the enhanced ARTS III terminal areas. These are presented in Table 8.5-1. This type of TIPS deployment would involve 29 terminal areas and a total of 89 FAA control towers.

8.6 ISSUES AND COMMENTS

TIPS - A Human Factors Evaluation

Advantages of TIPS: Basically, TIPS is a well-designed system which will provide significant assistance to the principal duty positions of the tower cab. The major benefits to be derived from TIPS include:

TABLE 8.5-1 EXPECTED PRIMARY TIPS DEPLOYMENT SITES

APPROACH CONTROL FACILITY	LOC IDENT	NO. OF FAA CLIENT TOWERS[7]
Atlanta Int'l.	ATL	3
Baltimore Washington Int'l.	BAL	1
Boston Logan	BOS	4
Cleveland Hopkins Int'l.	CLE	3
Chicago O'Hare Int'l.	ORD	4
Dallas Forth Worth Regional	DFW	4
Denver Stapleton Int'l.	DEN	3
Detroit Metro Wayne Co.	DTW	5
Honolulu	HNL	1
Houston Intercontinental	IAH	2
Jacksonville Int'l.	JAX	2
Kansas City Int'l.	MCI	2
Las Vegas McCarran Int'l.	LAS	1
Los Angeles Int'l.	LAX	3
Miami Int'l.	MIA	6
Minneapolis St. Paul Int'l.	MSP	4
New Orleans Moisant	MSY	2
New York Common IFR Room	N90	7
Philadelphia Int'l.	PHL	2
Phoenix TRACON	P90	1
Pittsburg Greater Int'l.	PIT	2
Sacramento (McClellan RAPCON)	MCC	3
San Diego (Miramar RATCC)	NKX	5
San Francisco (Oakland Common IFR Room)	090	5
Santa Ana (El Toro RATCC)	NZJ	4
Seattle Tacoma Int'l.	SEA	2
St. Louis Int'l.	STL	2
Tampa Int'l.	TPA	4
Washington National	DCA	1

a. Increased controller productivity through the rapid dissemination of flight data.

b. Increased control capability through an increase in the amount and variety of data readily available.

c. Increased effectiveness and efficiency through the increased ease of access to data. Relief from the need to mark and manipulate flight progress strips (FPS's) will permit controllers to pay more attention to their primary duties. However, some possible design weaknesses and potential solutions at man-system interfaces and at subsystem interfaces have been noted; these will be the subject of the remainder of this section.

Space Requirements and Integrated Consoles: Space in tower cabs is already seriously limited. TIPS equipment will increase space needs. Removal of FPS racks and the FDEP from the cabs will compensate for this increase to some degree, but the TIPS display - keyboard console must occupy prime workspace. Moreover, the TIPS console will be in competition with TAGS (in large towers) or ASDE and ARTS repeaters for display and keyboard space (already occupied by critical instruments) at Local Control (LC) and Ground Control (GC) Positions. A related consideration is the distraction and possible confusion experienced by a controller in having to select from among two or three similar keyboards and displays for various functions.

Therefore, a console that integrates ARTS and TAGS capabilities with TIPS seems desirable. This concept is particularly feasible with regard to keyboards, since TAGS and TIPS keyboards are modifications of the basic ARTS keyboard. An integrated keyboard might require more function keys than are needed for any one of the individual systems, but the space saved by eliminating two alpha-numeric keyboards will allow expansion, and, in some cases, multifunction keys will be suitable. Although such as effort falls beyond the scope of present MSDPs, it is worthy of consideration in view of the potential increase in controller efficiency and savings in workspace.

Although the displays for ARTS, TAGS and TIPS cannot be integrated onto a common surface, they should be combined into a standard console for LC and GC positions so that a controller will find all necessary data within a small area. Since ARTS and TAGS will have only a limited capability to display lineup lists, an adjacent TIPS display will be beneficial, permitting data tags to be dropped from all but the first few aircraft on ARTS and TAGS displays in crowded arrival or departure situations.

Status and Weather Messages: The space allocated for status and weather messages appears adequate for the present system. However, some proposed configurations of WVAS and Wind Shear may substantially increase the lengths of weather messages (particularly when separate sensor systems are available for each runway) and will increase the equipment to be reported on in status messages.

The format of status and weather messages is worthy of study in conjunction with ATIS and AV-AWOS formats. Generally, the information and weather messages carry the same information as the ATIS; it would be desirable to standardize a format so that the entry of status and weather data into TIPS will constitute the preparation of an ATIS message, thus conserving controller duty time. The format should be compatible with those proposed for automatic weather observing systems (such as AV-AWOS) so that weather entries may be automatic in the future. A standard ATIS-like format will also be compatible with automatic generation of ATIS in synthetic speech -- a development that could result from research on automated FSS functions.

Since weather and status data must be entered into the system at least once every hour and more frequently in times of rapidly changing weather, it may not be desirable for the controller (probably, Flight Data) to have to go to the IOT to make the entries. Consideration is recommended for adding weather and status entry capability to the TIPS keyboard functions.

Terminology - A possible point of confusion exists in the TIPS use of the term "cleared" (CLR) as a quick action function, because the term "clear" is generally used on computer control devices (including hand-held calculators) to remove data from certain registers and from the display. The quick action CLR of TIPS (which is used only at the Clearance Delivery position) does "clear" the flight plan display, but implies to the system that a clearance has been delivered. A controller inadvertently taking the CLR action to erase the flight plan prior to delivering a clearance might then forget to deliver the clearance. This possibility would at worst constitute an annoyance, but it can easily be avoided by changing the abbreviation to CLRD or CLD, or to DLD or DEL for "delivered". The terms "erase", "remove", "cancel", and "terminate" are unambiguous as used in TIPS.

Replacement of Flight Progress Strips (FPS): Replacement of FPS's is an objective of TIPS. At its present stage of design, TIPS makes available on its tower display most of the information currently printed onto FPS's by the FDEP. However the FPS is currently used as a medium for entering and recording much more information than is originally printed out by the FDEP. If TIPS can be modified to provide such capability, its effectiveness can be further enhanced. The following discussion will identify several classes of data currently entered by hand on FPS's and suggest ways in which TIPS capabilities might be adapted to handle this information.

Handwritten entries on FPS's serve the following functions: emphasis, reminders, checks, record of event times, record of special time data, and note pad. Each of these functions will be addressed with regard to types of entries, meanings of entries, and possible TIPS substitutes for these entries. Highlights of this discussion are summarized in Table 8.6.1.

Emphasis: Information of particular significance to controllers on printed strips is emphasized by circling or underlining, usually in red ink. For example, heavy jets or secondary airports are often underlined in red. In TIPS, the underline is currently programmed to identify ACID's of flight plans under revision on the GC display; additional use of underlining for emphasis should be feasible.

TABLE 8.6-1 TIPS SUBSTITUTES FOR HANDWRITTEN ENTRIES ON FLIGHT PROGRESS STRIPS

	TIPS SUBSTITUTES FOR HANDWRITTEN ENTRIES ON FLIGHT PROGRESS STRIPS		
FUNCTION	TYPES OF ENTRIES	EXAMPLES OF MEANING OF ENTRIES	POSSIBLE TIPS SUBSTITUTES
Emphasis	Word circled or underlined, often in red	Heavy jet	Underline
Reminder	Word circled or underlined, often in red	Information to be issued. Coordination required.	Symbol in prefix position or remarks position. Blinking symbol or field.
Check	Check mark added Word circled, often in red.	ATIS or restriction issued	Prefix symbol erased
Time Record	Time handwritten on FPS	Clearance delivered Coordination completed Departure/arrival time	Storage and off-line printout of entry actions and times
Special Time Data	Time handwritten on FPS	Requested/expected start time for gate hold	Quick entry and keyboard entry
Note pad	Controller's personal notes		Special function and keyboard entry IOT printout.

Reminder: Circling and underlining in red are also used to remind controllers of required actions, such as special information to be issued with clearances, or special coordination requirements. The remarks portion of the TIPS flight plan display may cover some of these reminders. As with emphasis, underlining could be used. Other possibilities for special reminders within the capability of TIPS include symbols in a prefix position on ACID blocks or the blinking of a symbol or word. Successful completion of the required function could result in removal of the reminder signal. Caution should be exercised to limit the use of blinking signals to those needing urgent attention. Blinking is already programmed to indicate revisions in flight plans and to indicate to CD that messages are waiting in a queue.

Check: A check mark is frequently entered on the FPS to indicate that a function has been accomplished. Removal of reminder symbols or features on TIPS could serve this purpose for many actions; where necessary, a substitute "check" symbol could be used.

Event Time: The times at which many significant events (e.g., arrival, departure, handoff, clearance delivery, message coordination) occur are handwritten on FPS's. These entries are another form of check marking but also constitute data required for record keeping. Since these events require an enter action in TIPS and a subsequent terminal transfer message in the system, the actions and associated times could be stored for periodic off-line printout.

Special Time Data: In some cases, time data must be recorded on FPS's when there is no associated action that could be automatically stored by TIPS (e.g., requested start time and expected start time for gate hold situations). For such data, a manual entry could be added to remarks, or, if the entry will be required frequently, perhaps a "quick action" function could be added that would only require selection plus the time entry.

Note pad: Individual controllers improve their efficiency by adding their own notes, symbols, reminders, and the like on FPS's. Within limits, this flexibility could be retained in TIPS by providing an opportunity to key in "note pad" entries that will be held with each aircraft's data only until handoff to another position.

Actual note pads are used by tower personnel in addition to FPS's. To simplify this usage, perhaps TIPS could be programmed to permit the controller to request selected data to be printed out on the IOT, giving him a sheet of paper to which he could add his notes. For example, LC might request a printout of the current arrivals ACID's. Not only could he add personal notes to this listing, he could carry it with him to various cab locations. When complicated control situations develop in today's system, controllers have been observed to pick up several FPS's, carry them to the window, and refer to them freqently while resolving the situation. Selected IOT printouts might add this flexibility to a TIPS-based system.

Conclusion: The foregoing suggestions have been offered, not as recommended design changes, but as illustrations of the fact that the basic design of TIPS has inherent in it enough flexibility and unexploited potential to provide the various controllers in the tower cab with a maximum amount of required data for a minimum amount of effort - without sacrificing the freedom and adaptability to today's ATC system.

REFERENCES FOR SECTION 8

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9. DATA PROCESSING SYSTEMS

9.1 ARTS II AND ARTS II ENHANCEMENTS

9.1.1 Introduction

The ARTS II is an air surveillance, data processing and display system for use in small to medium terminal area ATC systems. It is modeled after the ARTS III system but is implemented with simpler, less expensive equipment. Provision is made in the design for both TRACON and TRACAB installations. The principal difference between them is in the display subsystem, which consists, in the TRACON version, of a number of plan-view type displays and one tower BRITE subsystem, and in the TRACAB of a number of tower BRITE's only.

9.1.2 System Description

9.1.2.1 ARTS II Equipment - The system is composed of three subsystems which perform the functions of data acquisition, data processing, and data entry and display. The first interfaces with the sensor while the last interfaces with the controller.

The Decoding Data Acquisition Subsystem (DDAS) (1) accepts beacon video and azimuth information from a radar/beacon subsystem, (2) digitizes and decodes it and (3) transmits video to the display subsystem and digital data to the computer. A block diagram of the DDAS taken from the ARTS II specification[1] is given in Figure 9.1-1.

There are, besides various control signals, three kinds of input to the DDAS: video, triggers, and antenna synchronization. The DDAS then distributes video to the display subsystem, digitized range and azimuth data to the computer, and synchronization data, if required, to external equipment.

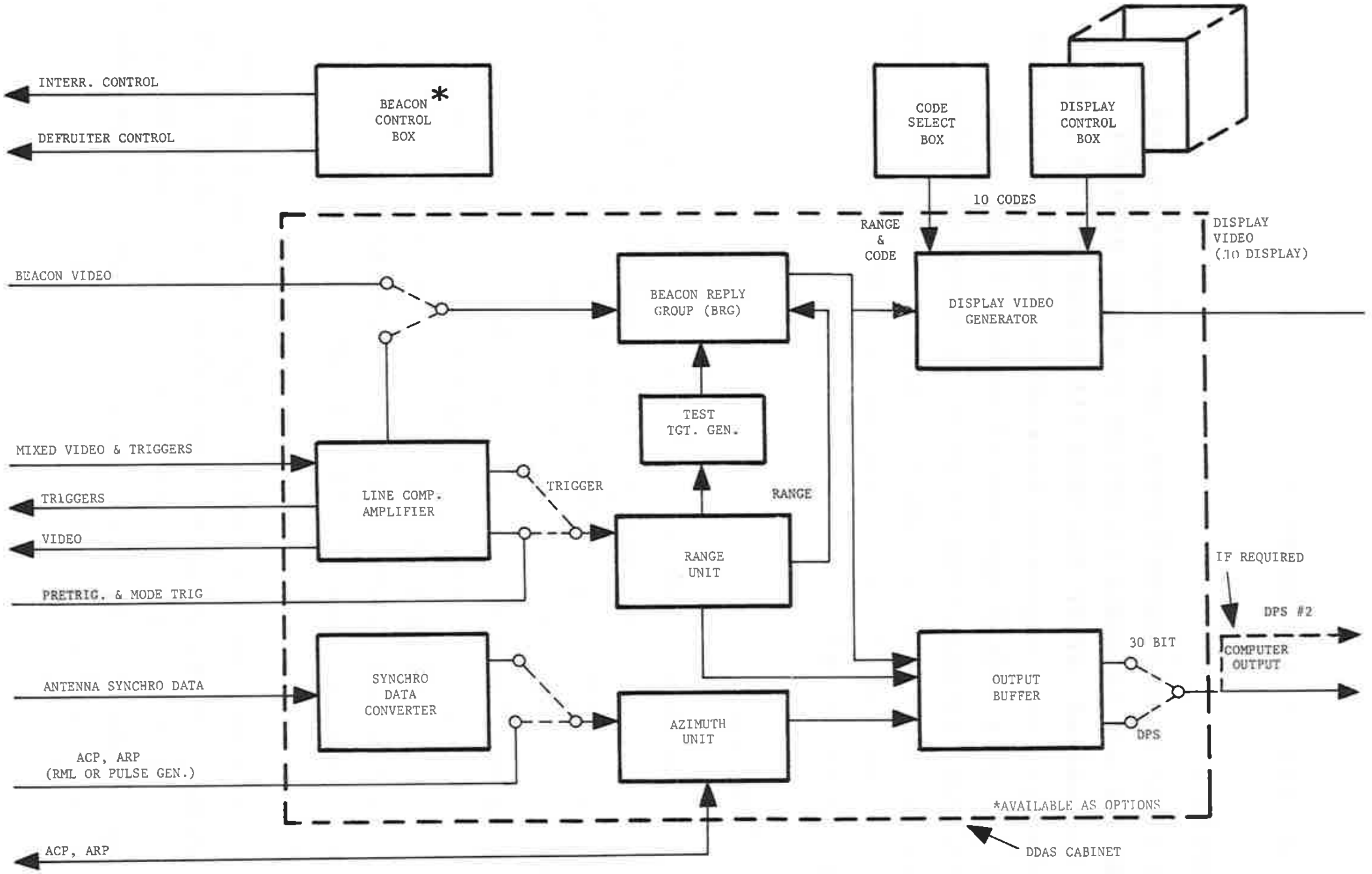

FIGURE 9.1-1. DECODING DAS BLOCK DIAGRAM

The Data Processing Subsystem (DPS) is made up of a Central Processor Module (CPM), a number of memory modules, I/O channels, peripheral adapter and control modules and a set of peripheral equipment. The intent of the specification was to describe a conventional, commercially available mini-computer system, rather than a specially built unit, for a number of reasons. Obviously, cost is the first motivation; given that commercial units can meet the reliability and performance requirements, they should cost far less than custom equipment. Secondly, the amount of support programming available and its relatively low cost, make the commercial units much more convenient for system development.

Two basic types of Data Entry and Display Subsystems (DEDS) have been developed, one which is a newly developed, self-contained unit for TRACON use and a second which provides output through existing BRITE subsystems for use in TRACAB and towers. Figure 9.1-2, again taken from the ARTS II specification, is a block diagram of the BRITE system as modified for use with ARTS II. The units to be installed in the tower cab, shown on the right-hand side of the diagram, are the BRITE display and control panel (to be supplied by the government) and the alphanumeric keyboard, Position Entry Module (PEM) and control panel (to be developed as part of the new system). The computer interface to be supplied with the BRITE equipment will be so designed that the BRITE subsystem will appear to the computer exactly like the TRACON display subsystem. Therefore, the TRACAB and the TRACON may be serviced by the same computer program without differentiation as to equipment, and also, a Tower BRITE position can be treated just like any other position.

The alphanumeric keyboard and the PEM are shown in Figure 9.1-3, taken from the specifications.[1] The keyboard, which is to have maximum dimensions of 8 1/2 inches square and 3 1/2 inches deep, will be connected to the console by a flexible cable, allowing it to be moved to any convenient position in the work area. It will be backlit, as well, so that its location can

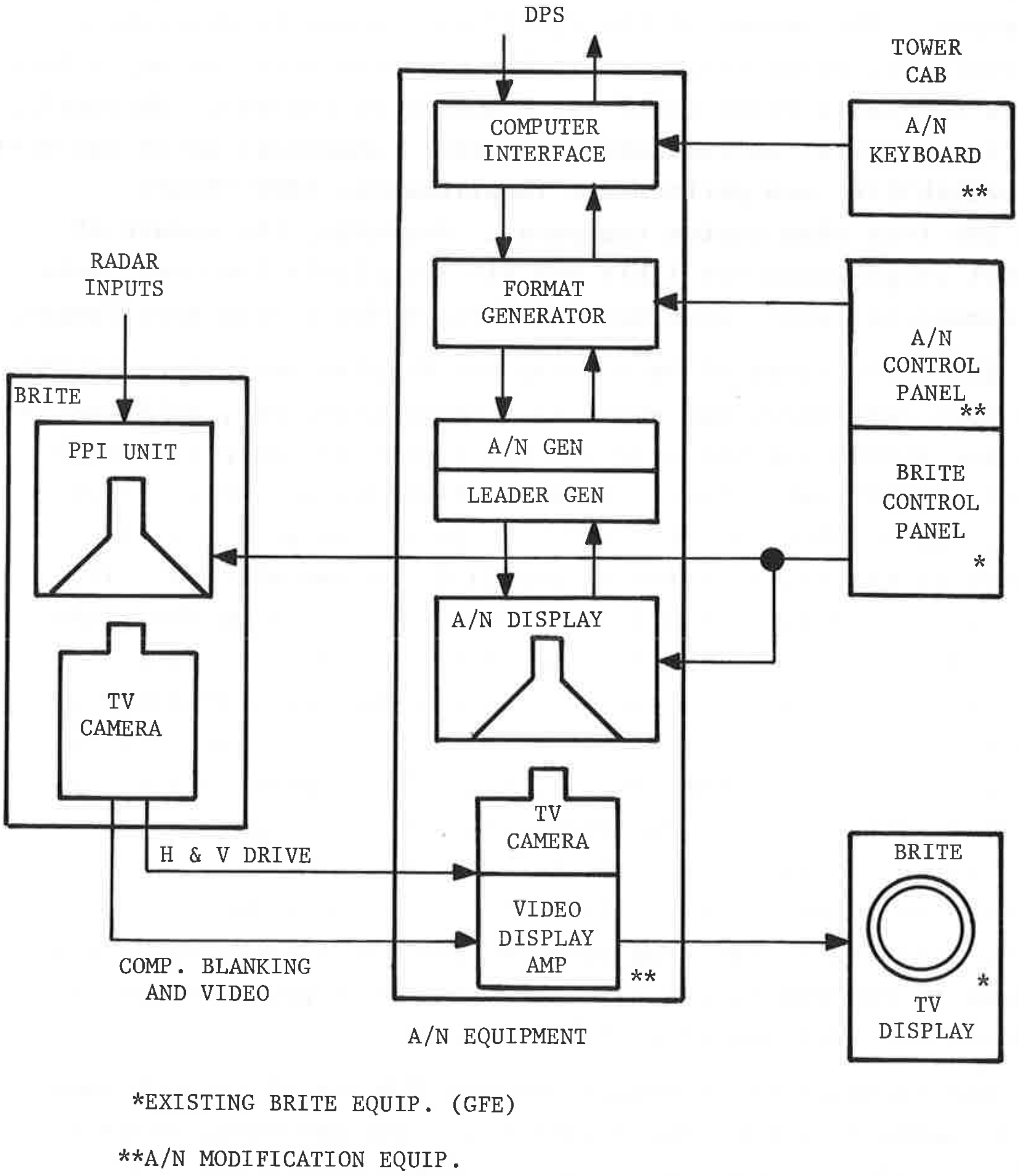

FIGURE 9.1-2. BRITE A/N MODIFICATION BLOCK DIAGRAM

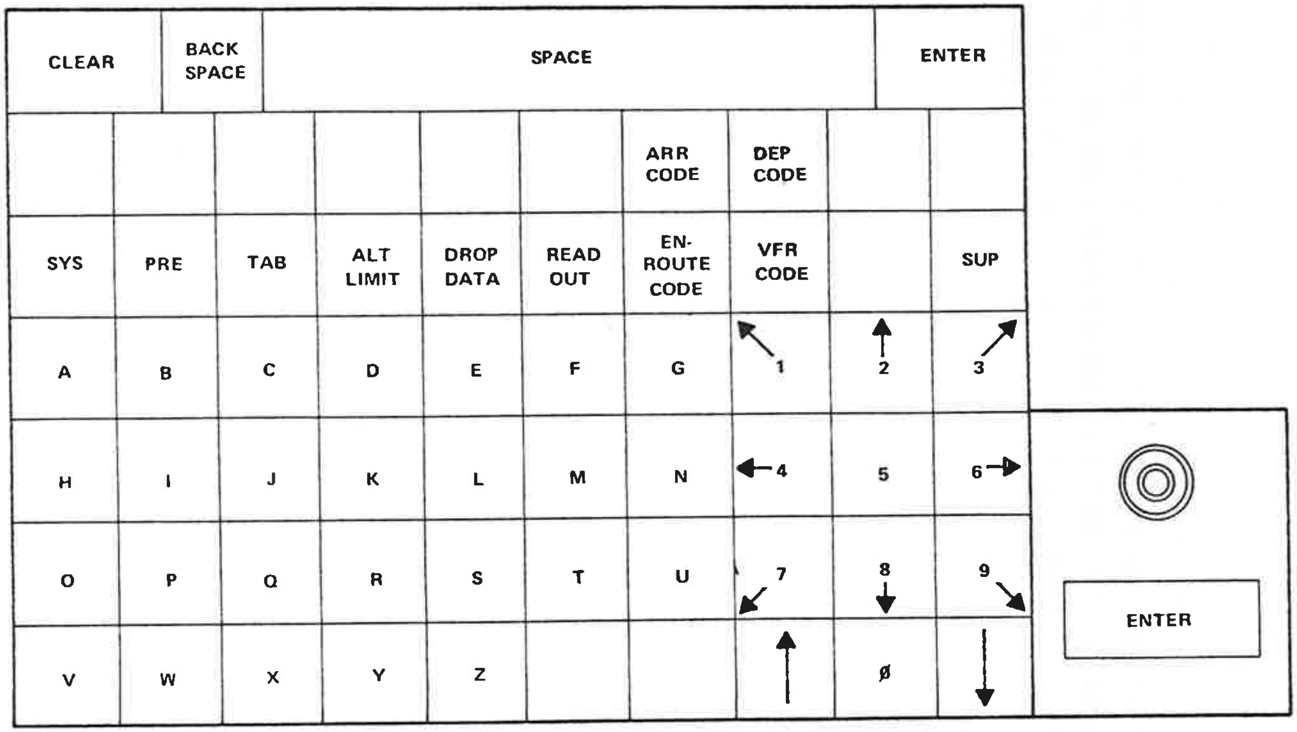

FIGURE 9.1-3. ALPHA-NUMERIC AND FUNCTION KEYS

be independent of the available lighting. The PEM may be mounted on either side of keyboard for the convenience of the operator.

The remaining controls-- quick-look, beacon filter, and inhibit switches, as well as controls for the alphanumeric part of the display - are to be mounted together as a panel, shown in Figure 9.1-4 again taken from the specification. This panel is to be made so that it can be attached directly to the present BRITE control panel. Any and all additional equipment needed to modify the BRITE equipment must fit into a rack 70 inches high, 27 inches wide and 27 inches deep, on which a maintenance TV monitor may be placed.

9.1.2.2 ARTS II Functions - The ARTS II computer program is organized as a Master Control Subprogram and four major operational subprograms:

a. Input Processing

b. Functional Processing

c. Beacon Input Processing

d. Display Output Processing

The Master Control subprogram schedules the operation of the operational subprograms in response to timer interrupts, external interrupts, and flags set by other subprograms.

The Input Processing Subprogram processes the inputs from all of the devices connected to the DPS: the DDAS, the DEDS, system peripherals and, if present, interfacility Teletype lines on high-speed modems. This processing accomplishes such tasks as communications protocol handling, validity checking, code conversion and message formatting. Each input device or subsystem will require a set of special responses or actions on the part of its input processing routine; the response to the input from the DDAS is merely to buffer the data block and flag the Beacon Processing Subprogram when reception is complete, while the reaction to input from the DEDS is the interpretation of the received character and the carrying out of any implied function.

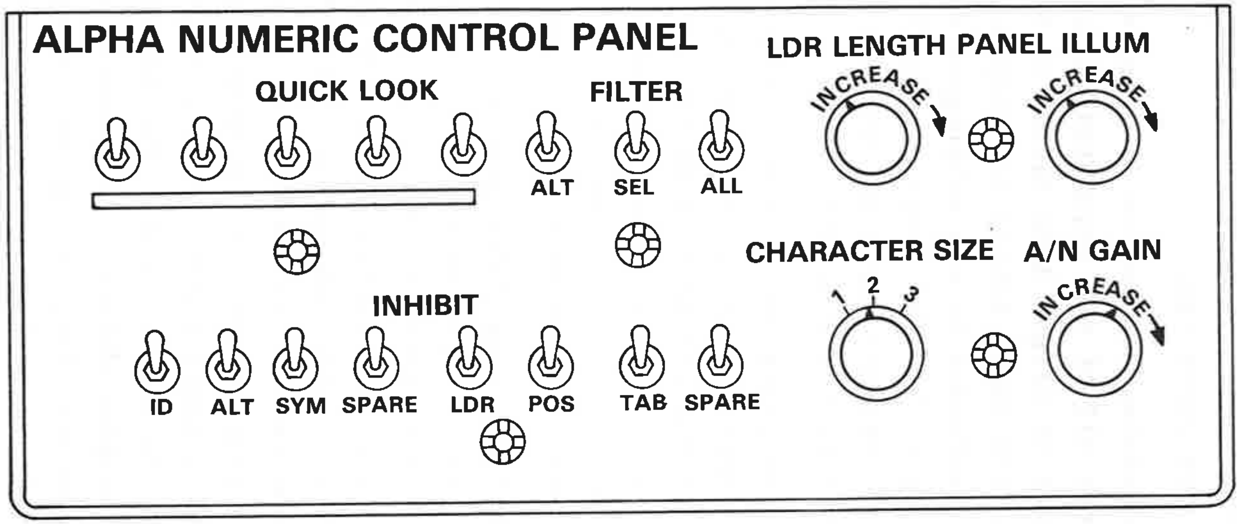

FIGURE 9.1-4. ALPHA-NUMERIC CONTROL PANEL

In particular, this subprogram must assemble keyboard messages in the preview area of the display until the ENTER character is received, it must check the message for validity according to the pre-set criteria for each message type, and it must transfer the input data to the proper tables in memory and flag the proper functional task for later operation.

The Functional Processing Subprogram is a collection of routines which carry out all of the requested manipulations of flight data, maintenance of flight data tables in the memory, and selection of data from these tables for display. Table 9.1-1 lists the tasks to be performed by the subprogram with a single phrase in explanation of each. The program is to be organized in a modular fashion so that new tasks may be added, or old ones modified, with no effect on the remaining tasks.

The Beacon Input Processing Subprogram is responsible for accepting beacon reply messages (after they have been buffered by the Input Processing Subprogram) on a sweep-to-sweep basis and for producing target reports containing range, azimuth, beacon code and mode C code, the last-named being converted to altitude by the appropriate Functional Subprogram task mentioned above.

The Display Output Processing Subprogram has the job of preparing and maintaining all display tables used in the system and of managing the I/O command lists in such a way as to insure that all of the required data is displayed. There are basically two tasks to be accomplished by this subprogram. The Alphanumeric Data Processing task has the responsibility for searching the current data tables to find the data which should be displayed, whether Full Data Blocks, Limited Data Blocks, single symbols, or tabular data, according to the particular display and the setting of its controls. The Display Output task prepares and arranges the I/O command list for each display, taking into account the time available both within the individual alphanumeric write periods and within the refresh cycle.

TABLE 9.1-1. FUNCTIONAL PROCESSING SUBPROGRAM TASKS

Data Acquire
- Establish aircraft record as a result of an input message

Interfacility Message Processing and Generation
- Process and prepare interfacility messages

Magnetic Tape Processing
- Process flight data pre-stored on magnetic tape

Mode C Conversion
- Convert Mode C replies to display format and correct for current barometer reading

Acquire/Drop Data Block
- Acquire or drop beacon code/ACID associations either automatically according to criteria or by manual entry

Altitude Filtering
- Select those Limited Data Block targets whose altitudes are within the altitude filter limits

Mode C Reply Processing
- Select unassociated Mode C reports and prepare them for display

Coordinate Conversion
- Convert range and azimuth coordinates to Cartesian

Next Available Discrete Beacon Code
- Generate next available code when requested

Time Display
- Maintain current time-of-day in the display table

Special Code Processing
- Process and prepare for display all Emergency, Radio Failure, and Special Code messages

Tab List Processing
- Prepare list of active targets without reply and unassociated qualified aircraft for display

Quick Look
- Set up proper indicators to display requested quick look data

Tabular List Maintenance
- Maintain Tabular List and System Data at each position

Hand-off Processing
- Carry out prescribed actions to effect the hand-off of a target to another position

9.1.2.3 ARTS II Enhancements - Enhancements to ARTS II systems can be in both equipment and function; the computer system is to be designed to allow for certain types of expansion and the computer program is to be made modular to allow the addition of new functions.

9.1.2.3.1 Equipment Enhancement - The system can be expanded in computational power-by addition of a second CPM, in memory - by the addition of memory modules, in communications capability - by addition of interfaces, in controller positions - by the addition of displays and keyboards, and in reliability - by the addition of a redundant DDAS. Not all of these enhancements are independent, however, since the dual CPM and additional memory might be required to drive additional displays and would be required if the redundant DDAS were provided. The maximal configuration would have two CPM's, two DDAS (one connected to each CPM), at least 96K of memory, high-speed and low speed communications interfaces, ten displays plus two maintenance monitors, and twenty keyboards.

9.1.2.3.2 Functional Enhancement - Any number of functional enhancements could be developed for ARTS II system by virtue of the modular design of the software; two were explicitly mentioned in the specification: Flight Data Delivery and Beacon Tracking.

The Flight Data Delivery feature provides for the inclusion of six or more tabular displays on which flight plan data can be presented to the controllers. No description of the functional operation of this feature is given.

Beacon Tracking, however, is well understood from the ARTS III experience. Its addition to ARTS II should be relatively straightforward if sufficient computing power is provided in the basic design.

9.1.3 System Integration and Interfaces

9.1.3.1 Interaction with Controllers - The obvious parallel between ARTS II and ARTS III extends to the way the systems interact with the environment into which they have been or will be introduced. The controllers in the tower will have new capabilities added to their existing BRITE displays or they will be given a BRITE for the first time. Their use of the new information should follow the ARTS III BRITE useages closely, introducing no new problems.

The introduction of ARTS II into a TRACAB will again provide predictable interactions with controllers who have been accustomed to no radar approach control, approach control with no processing or with equipment of lesser capability, such as TPX-42. Given that the new equipment fits in the cab and does not introduce physical problems, such as impeding movement of controllers or blocking a critical viewing angle, the switchover to ARTS II should be trauma-free.

9.1.3.2 Interaction with Other Systems - Since ARTS II is targeted for use in small airports which are not satellites of larger terminals, there is little likelihood that other MSDP systems will be co-located, except perhaps DABS and MLS. The interaction between MLS and ARTS II will be minimal unless an interface is specifically provided. As things stand, ARTS II will have just dropped, or be about to drop, a track at the time it begins to make use of MLS.

The interaction between ARTS II and DABS is likely to be more complex since DABS will be providing the basic data input now provided by ATCRBS and, moreover, the form of that data and the communications medium on which it is transmitted are different. There will have to be some reprogramming of ARTS II routines to make use of the target reports provided by DABS through a high-speed data line. New functions will have to be developed from scratch to enable ARTS II to make use of the DABS data link capability.

9.1.4 Failure Modes and Backup Provisions

ARTS II is not expected to be a fail-safe type of system, although provision has been made in the larger configurations for a redundant DDAS. In general, the reliability and repair requirements have been made stringent enough to provide trouble-free service for long periods of time with relatively short periods of disruption. The MTBF for the Data Processing Subsystem is supposed to be 1500 hours with a MTTR of one-half hour.

When there is a failure in the ARTS II system not involving the radar itself, the analog signal will still be available on the displays as backup; a failure in the sensor will require reversion to a manual operation.

9.1.5 System Status and Development/Deployment Program

9.1.5.1 ARTS II Program - The ARTS II program is in full swing, with five systems built and undergoing tests at the Burroughs factory: reliability testing on systems A and B, software on system C, environmental on D, and maintainability on E. This activity is expected to end in September of 1977 and the systems will then be shipped to the users. The first will go to NAFEC, the second and fourth to the FAA Academy, the third to Edwards AFB and the fifth to Lovett AAF. In January, deliveries will start in earnest at the rate of three per month.

9.1.5.2 ARTS II Enhancements

Although Air Traffic has expressed great interest in adding such functions as beacon tracking to ARTS II, no statement of requirements has been received at SRDS and hence there is no activity to produce ARTS II enhancements nor is any funding available now or in the FY 78 budget.

9.1.6 Issues and Comments

Although the first production units are still under tests, the prospect for delivery of the ARTS II systems during the next five years seems quite good. There do not seem to be any issues to be raised with respect to integration with other MSDP systems in the tower cab, except for MLS and DABS, as noted above.

9.2 ARTS III ENHANCEMENTS

The ARTS III is a complex system of sensors, data processing equipment, displays and computer programs which have been under development for about ten years. An initial version, called the Beacon Tracking Level (BTL) system, has been operational in 61 TRACONs for about four years. It is planned to enhance the capabilities of these limited systems in stages, until 1) they are able to supply as many automated services, at whatever level is necessary, as are useful and effective at each facility, and 2) they are completely reliable, fail-safe, fail-soft systems in continuous operation twenty-four hours per day.

The enhancements are coming about in three ways: by planned, coordinated steps; by ad-hoc retrofit and by special unique developments for particular sites. The first of the coordinated steps, the so-called ARTS IIIA Enhancement which is currently being procured, will be discussed first.

9.2.1 System Description

9.2.1.1 ARTS IIIA Enhancements - The first package of enhancements of the Beacon Tracking Level ARTS III is called, in its procurement version, ARTS III A. It consists of twelve new hardware elements and five new software capabilities.

9.2.1.1.1 New Hardware - The new hardware modules[2] to be designed and procured were meant to provide three new capabilities: multiprocessor operations, remote data acquisition and display, and use of primary radar in target tracking.

The additional modules for multiprocessor implementation have, for the most part, been under development for many years, prototypes having been built and demonstrated under R&D programs. Among these, the Reconfiguration and Fault Detection Unit (RFDU) will allow the detection of faults in IOP and memory modules and the automatic reconfiguration of the computer complex, resulting in fail-safe operation; the Central Memory Access (CMA) module will allow large complexes (more than four IOPs) and will help in reconfiguration actions.

The Peripheral Switch Module (PSM) has been developed to allow the manual switching of peripherals such as magnetic tape systems, communications adapters, Teletypes and beacon data acquisition subsystems (BDAS). It also allows each peripheral to be placed off-line for maintenance without interfering with the continued operation of the system as a whole.

A set of new peripherals, with control elements, has been specified to allow for more flexible system operation; the set includes card readers, magnetic tape units, disc systems, and printers.

Remote data acquisition will be facilitated by an Azimuth Distribution Unit (ADU) which will provide interfaces to accept azimuth data from remote or local sources and distribute them to a variety of data acquisition and display subsystems.

Remote display will be made easier by the development of a group of components. The Multiplexed Display Buffer Memory (MDBM) will allow a number of displays to be driven by a single module at an arbitrary distance from the computer; the display information is stored in the MDBM making it necessary to transmit only changes and updates from the computer. This both reduces the communications load and relieves the computer of the display refresh task. (A similar device, called the Interface Buffer Adapter Generator (IBAG), has been specified which will drive Plan View Displays, although presumably not remotely.)

An Interfacility Communications Multiplexor (ICM) with appropriate adapters will be developed to allow efficient operation of remote equipment.

Primary radar data was to have been digitized and transmitted to the ARTS computer by a unit called the Radar Data Acquisition Subsystem (RDAS), which, however, has been replaced by a newer unit called the Sensor Receiver and Processor (SRAP) discussed below (Section 9.2.1.2.3).

9.2.1.1.2 New Functions - "The purpose of this enhancement is to elevate a number of Beacon Tracking Level Systems (BTL) to Radar and Beacon Tracking Level Systems (RBTL) ARTS III A. In addition, it is to add Continuous Data Recording (CDR) capability to all ARTS III systems. As a minimum, the added improvements are to provide:

a. Processing, tracking, and display of all primary and secondary radar video from one or more ASR systems.

b. Improved quality and performance of the existing ARTS III tracking capability by the acquisition and display of all radar derived (primary and beacon) aircraft targets.

c. Improved fault detection and isolation.

d. Capability for continuous automation operation at levels consistent with system availability when one or more system elements have failed.

e. Capability for continuous recording of input, output and system status data.

f. Capability for further modular expansion of hardware and software.

g. Capability for twenty-four hour daily operation in support of operational requirements.

h. Capability for further modular expansion of hardware and software".[3]

Smaller systems, which will not be upgraded to include primary radar processing, will remain as BTL systems with CDR capability. They will receive a mass-storage (disc) subsystem and a printing subsystem, with the required software to:

1. extract a large specified set of data from the ATC system while it is operating,

2. record an operator-selected subset of that data onto the disc,
3. transfer the data from disc to tape, while the system is operational,
4. reduce and edit the data, and print the results, while the system is not operational, and
5. use the disc for storage and loading of operational and utility programs.

This will allow the recording of important operational data continuously on the disc, overwriting the oldest set each time. If a time period produces data of lasting interest, the disc load can be saved on magnetic tape and reduced and edited off-line, all without interfering with the normal system operation. This is a means for collecting historical, and perhaps legal, data which can be used among other things, to analyze and improve system operation.

The last capability listed above is essentially a useful and desirable by-product which will make day-to-day system operation simpler and more convenient.

Those systems upgraded to RBTL systems will be given a CDR capability much like the one just described plus four other capabilities:

1. radar target detection and processing, which will allow the system to become aware of all targets within radar coverage rather than just those which are beacon equipped.
2. radar-beacon correlation and tracking, which will allow the system to maintain surveillance over all targets and improve tracking of beacon-equipped targets,
3. multi-processor operation, under a multi-processor executive, which will allow flexible utilization of the resources of the system as augmented, and
4. failure detection and automatic reconfiguration and recovery, which, besides the obvious functions, makes possible continuous twenty-four-hour operation.

When the ARTS III A program is complete, 28 terminals will be equipped with ARTS multi-processor systems, ten of which will be large dual-beacon systems.

9.2.1.2 Functional Enhancements - One of the original design concepts under which the ARTS III was developed was that of modularity - that the system was made of independent blocks with each dedicated to a function of the system. This being the case, additional modules, or functions, can be added to the system with the minimum effort, as long as there is memory space and processor capability to handle them. A number of such enhancements have been under development for some time and others are being planned or at least discussed. One function has already been fielded in response to a perceived immediate need.

9.2.1.2.1 Already-Installed New Feature - The Minimum Safe Altitude Warning (MSAW) function[5] has been, or soon will be, installed at all ARTS III TRACONS. It is a program module which checks the altitude of all mode C targets to check whether they are, or might be expected soon to be, below a safe altitude. When this condition is detected, an alarm is given by the system to the controller.

For the general area around the terminal , the program compares the current report altitude of the aircraft to a prestored maximum height of terrain or obstacle within the two mile by two mile grid square over which he is flying. If he is less than 500 feet higher than the obstacle, the alarm is given. Otherwise, a straight line three-dimension position and velocity estimate is made for 30 seconds into the future. If at any point along that path, the aircraft is predicted to be less than 300 feet above the maximum grid height, the alarm is given. If no alarm, a third check is made to see if the aircraft could clear all surrounding grid heights by 300 feet by climbing at 5 degrees from the just-calculated 30 second position. Failure to clear is cause again for an alarm.

Other logic is used during final approach and in the vicinity of satellite airports to check for proper alarm conditions. No check is made within a specified area immediately surrounding the runways, nor for aircraft having departure status.

The alarm is presented on the CRT by displaying the blinking characters "LOW ALT" above the ACID in the data block of the affected track. In addition, an aural alarm is sounded to attract the controller's attention to the scope. Those aircraft for which MSAW surveillance has been inhibited will have the characters INHB displayed in their data block.

9.2.1.2.2 Special Configuration Under Procurement - A special maximum-size ARTS installation is being procured for a new TRACON for the New York Terminal Area.[4] This configuration, with eight IOPs and 16 memory modules, handles input from four radars and services three major airports. The performance expected from this assemblage will stretch the ARTS technology to its limit.

9.2.1.2.3 Features Under Development - There are a number of functions to be performed by ARTS which are under development by SRDS for inclusion in future enhancement packages. These include Conflict Alert (CA), Metering and Spacing (M&S), and Remote Radar Processing.

The Conflict Alert function will monitor the paths of the aircraft in the Terminal Area and extrapolate them ahead in time to see if there is a possibility that two or more of them will be in conflict with one another. If so, then the controller will be warned of that possibility in time to take action to resolve or forestall the conflict.

Metering and Spacing is the name of a function which sequences, meters, and controls the spacing of aircraft during their approach to the airport. Sequencing is the process of arranging the order in which the aircraft cross the entry fixes so that they will arrive at the runway in the correct order. Metering is the process of assigning an exact time to each aircraft to start its approach by crossing the entry fix, so as to achieve and maintain a specified arrival rate at the runway. Spacing is the process of monitoring the path of each approaching aircraft and causing its course and/or speed to be adjusted so that the proper separation will be maintained during the approach and at the runway threshold.

Remote Radar Processing involves the development of new hardware, to be located at the radar site, which will take over the target detection function from the IOP. The unit is called the SRAP and will replace the BDAS in ARTS III A systems, will provide an RDAS capability and will take over the radar and beacon target detection and radar-beacon correlation processes. The SRAP is able to do all of this because it will have considerable processing power itself, being a microprogrammed, special purpose computer. The use of this device will have the effect of lowering the communications bandwidth requirements from the site and also reducing the processing requirements in the ARTS computer.

A special ARTS III configuration is being installed at the Tampa, Florida TRACON which will use several of these new equipments and computer programs in what amounts to an operational prototype of an ARTS III A site. A general block diagram of the configuration is given in Figure 9.2-1. Three new equipment modules will be tested: the SRAP, mentioned above; the Remote Display Buffer Memory (RDBM) and the Tower Cab Digital Display (TCDD). The latter two together will provide the remote tower with a bright all-digital display with full keyboard capability including 'quick-look.'

9.2.1.2.4 Other Features Planned or Discussed - Planning for some other new ARTS functions is still in the initial stage. Three, in particular, are Control Message Automation (CMA)*, Flight Data Handling (FDH) and All-Digital System. In each case, the name describes the function fairly well. The Control Message Automation function would prepare command messages automatically, or automatically with controller monitoring, for transmission over

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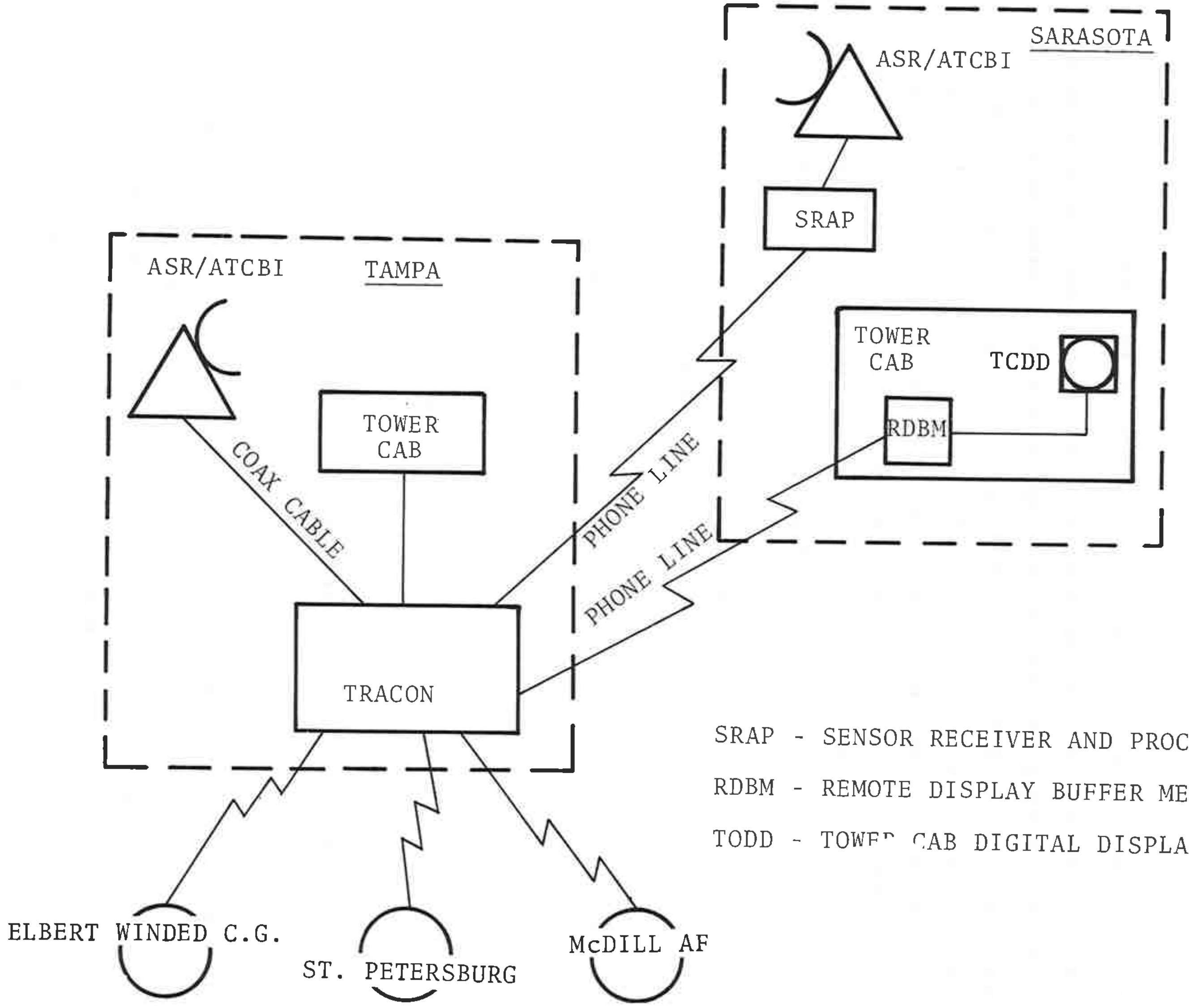
*This is sometimes seen in the literature as Command Message Automation.



SRAP - SENSOR RECEIVER AND PROCESSOR

RDBM - REMOTE DISPLAY BUFFER MEMORY

TODD - TOWER CAB DIGITAL DISPLAY

FIGURE 9.2-1. TAMPA/SARASOTA ENHANCED ARTS CONFIGURATION.

some type of data link as yet unspecified. Flight Data Handling appears to be an ARTS-based version of the system being developed as TIPS. The All-Digital System is a development program which seeks to replace the current hybrid analog-digital display with one which is only digital, essentially discarding the broad-band video and placing reliance on synthetic displays generated by the data processing subsystem. In each of these cases, there are considerations which make implementation unlikely under present conditions.

9.2.2 System Integration and Interface

Interaction with Controllers - The implementation of ARTS Enhancements will, in general, have only a marginal effect on tower cab operations. All functional improvements are available, of course, to the ARTS Tower position, through the BRITE display and the keyboard, but for the most part they are of little operational use to tower personnel. This limited effect is described below for the various functional enhancements.

MSAW - This function adds a new feature (a flashing warning) to the ARTS displays, including the BRITE displays in tower cabs, if they have alphanumeric capability. It also adds an aural alarm to the cab equipment. Generally this will be beneficial to tower personnel in giving them earlier warning of developing situations and permitting them to avoid hazardous situations by issuing more timely warnings. Since the warning flashes and is backed up with the aural alarm, monitoring the displays should not be more difficult in general as a result of this new feature. Automatic resolution of MSAW incidents and transmission of warnings via datalink could result eventually in a decrease in the controllers' workload. Possible problems connected with MSAW are: (1) additional stress and work for controllers if the system should have high false alarm rates, and (2) interactions with other warnings and alarms (Terminal Conflict Alert, WVAS, Wind Shear, and possible future systems).

Conflict Alert - This extension of Conflict Alert to the terminal area proposes to flash a warning on the ARTS displays at the same data block position as MSAW and to share the MSAW aural alarm. Thus the comments regarding MSAW apply here. There may be a potential for confusing the controller should a conflict and a low altitude problem develop together.

Metering and Spacing - Generally, automated metering and spacing will have its greatest beneficial effects on controllers in ARTCC's and TRACON's. Local controllers will receive aircraft optimally spaced; however, the resulting increase in arrival rates will require close attention in monitoring and could increase the stress of the job. Metering and spacing enhancements in ARTS III should not result in additional controls, displays or duties in the tower cab.

Remote Displays - The development of remote display capabilities will add one or more BRITE (or equivalent) displays in satellite towers. The advantage to the controller will be the availability of additional information, while the disadvantges will be the crowding effect of the displays and control panels and the additional tasks associated with adjusting and monitoring the displays. Overall, the effect should be similar to that already met in the smaller tower/TRACON installations.

Control Message Automation - If some kind of digital data link is implemented, through DABS or other means, then it will be possible to relay command and control messages directly from the ARTS computer to the aircraft. As was noted previously in the discussion on Metering and Spacing, most of the impact would be on controllers in TRACONs, although local controllers in the tower would have to understand and follow the course of the commands being issued prior to acceptance of handoffs.

The approach control function in a system that had features like automatic message generation, digital voice data link, and automated metering and spacing was tested through simulation.[7] Within the limits of simulation (one runway, no curved MLS final approaches, 2-mile separation), the automated features resulted in a 57 percent improvement in message transaction times at maximum traffic load. The most effective mode of operation tested involved the automatic generation of commands to aircraft, a 2-second appearance of the command on the aircraft's flight data block in the ARTS PPI display, followed by automatic transmission of the message, unless the controller manually rejected the command and took over on voice link. Possible disadvantages to this mode include greater susceptibility to blunders through loss of human control and crowding of display symbols with the added command line on data blocks. Considerable additional simulation will be needed before final techniques could be adopted, but this study provides an encouraging preview of the benefits to the approach controller of command message automation.

Although Local Control use of automated message generation and transmission has not yet been simulated, we can foresee the necessity for close coordination between Local and Approach Control, particularly in providing arrival gaps for departures when the same runway is the use for both.

Fail-Safe/Fail-Soft - Implementation of Fail-Safe capabilities will benefit controllers by virtually eliminating disruptions in operations due to parts failures. In fail-soft systems, such disruptions will be minimized; however, failures occurring when the system is operating close to capacity will cause the loss of some functions, the slowing down of others. Since the functions to be affected will be selected on a priority basis, even in this worst-case situation the controller will be able to continue functioning effectively.

9.2.3 Failure Modes and Backup

9.2.3.1 ARTS Fail-Soft and Fail-Safe - The ARTS system was planned from the start to provide the continuous, reliable operation required for ATC operation. This capability will be attained only when the ARTS III A enhancement is fully installed, at which time fail-safe and fail-soft operation will be demonstrable. Fail-safe operation is characterized by the ability of the system to recover automatically within some specified short time from the failure of any single component (data acquisition subsystem, processor, memory module, display subsystem), to restore critical data and displays and to provide full pre-failure system capability. Fail-soft operation is system operation at a reduced level following multiple component failure, the degradation being at the expense first of non-essential services and excess capacity and then of gradually higher priority functions and capacity as the need arises.

Thus the introduction of the ARTS enhancements will increase the reliability of the system to the point where backup provisions will almost never be needed.

9.2.3.2 Tower Cab Backup - Failure of the "Tower" ARTS position, because of a failure in the unduplicated BRITE system, will force a return to use of voice communications with the TRACON and some form of note-keeping or scratch pad operation. Such backup is probably sufficient for short periods of time and light loads, but would not be tolerable for very long or under really stressful situations.

9.2.4. System Status and Development and Deployment Program

9.2.4.1 ARTS IIIA Program - The first package of ARTS enhancements is being procured by Airways Facilities from UNIVAC under a fixed-price contract.[8] Work has been going on since July 1, 1976; the next major milestone will be the Factory Operational System Test (FOST) in November or December of 1977. Sixty days later, the first ARTS III A system will be installed at Minneapolis/St. Paul Airport. A schedule of subsequent installations is expected to be available about July 15, 1977.

Although the program is progressing satisfactorily, there are some areas of concern to FAA, including possible problems with the disc subsystem, the support software and the processing capacity at the proposed New York TRACON. At the present time, it appears that UNIVAC will have to solve the disc problem by adding some buffering hardware to the disc/IOP interface, that additional specifications will have to be written and funding obtained for support software, and that the New York system will have to be respecified with lower requirements or additional processing capability will have to be found, possibly by means of distributed processing.

9.2.4.2 Development Program

Conflict Alert - The Conflict Alert function is currently under development as Task 4 of the Phase II ARTS Enhancement program, under a Cost-plus-Fixed-Fee contract with UNIVAC. The first version will be used with the Basic ARTS BTL system (currently, A0.12); it will produce conflict warnings among those Mode C aircraft being actively tracked and assigned to a common controller position. The system has been demonstrated at NAFEC using the Enhanced Target Generator/Terminal Area Test Facility (ETG/TATF): the results of the evaluation of the demonstration should be available about July 15, 1977. Meantime, a system to be tested in the field at Houston is expected to be ready in August 1977.

Preliminary measurements indicate that conflict alert will require in the vicinity of 6 percent of a IOP for processing 40-70 tracks and will need about 9K words of storage for a single-beacon system (about 11K for dual beacon). These numbers are high but relatively encouraging when compared to the 20 percent of a IOP originally projected.

Metering and Spacing - A limited version of terminal Metering and Spacing was tested in December 1976 at NAFEC using the TATF and Digital Simulation Facility (DSF) with pilots and controllers participating. The results were encouraging enough to warrant a field test to be carried out at Denver, starting in August or September 1977 and lasting for about three months. These tests have recently been postponed however, until the spring of 1978 because of the impact of the Profile Decent procedures now in force at Denver. New design data for the Denver tests should be available in August 1977.

The system being tested is not intended to be implemented as an operational program but is meant to be verified conceptually under operating conditions.[9] Every attempt will be made to keep the M&S operation separate from the ARTS program. M&S will be run in a specially installed, dedicated IOP with its own memory. The only contact between ARTS and M&S will be via a shared memory, where beacon data will be available to the new function and where it can leave commands to be displayed. The M&S program will contain its own tracking program - a beacon-only modification of the Radar-Beacon Tracking Level (RBTL) tracker - and will operate under its own executive.

This program will provide a very limited capability only; it is written with the Denver geometry in mind and then only for one runway. Two approach geometries are provided in order to allow data from each to be collected. A missed approach geometry is specified and two performance classes, high and low, are accommodated. Besides being integrated into ARTS III, an operational M&S must:

1. provide for multiple runways and runway reconfiguration,
2. be in the form of a standard program plus adaptation data,
3. be compatible with terminal conflict alert and microwave landing systems, and
4. handle multiple airports and conflicting satellite airport approaches.

<u>Remote Radar Processing</u> - Preparations are underway for testing the installation of Tampa/Sarasota described in Section 9.2.1.2.3. Data is expected to be transmitted through the SRAP at Sarasota in late May 1977 and System On-Site Testing (SOST) is expected to start in August 1977.

9.2.5 Issues and Comments

The ARTS III impinges on the tower operation only to the extent that the ARTS BRITE and keyboard are used by the tower controllers. The interface is well established for the basic ARTS IIIand it remains to be seen what effect the ARTS III A and other enhancements will have on that interface. Obviously, there are possibilities which could lead to problems but they seem to be well controlled at this point.

An area of concern could be in the addition of new functions which might stress the system to the point where controllers begin to experience unpleasantness or even difficulty. This could come about if the data processing capacity were approached, say, under peak load conditions, so that system response time was increased to an unacceptable level. It might also happen that so many functions and options were provided that the controller could no longer keep straight what was being displayed to him on the limited ARTS display surface.

Obviously, these are matters of great concern to numbers of people -- system designers and users -- and do represent approaches to the limits of the system capability and will become more critical as time goes on.

9.3 FLIGHT SERVICE STATION (FSS) AUTOMATION

9.3.1 Introduction

Flight Service Stations provide two major services to the General Aviation community: weather briefings and flight plan filing. The plans for the automation of FSS's call for consolidation of the stations into about twenty hub stations, each equipped with a computer. Users in the region surrounding the hub would obtain service via any of a variety of I/O terminals connected to the computer by dial-up phone lines. Weather briefings would be available in great detail through Pilot Self Briefing (PSB) terminals which could range in complexity from ones with full graphic capability, including hard-copy output, through simple home TV adapters to the telephone itself, giving the listener a computer-generated voice response. Flight plans could be entered through the keyboards of PSB terminals, through a simple hand-held keyboard or a touch-tone telephone. A few specialists at each hub would be available to assist users having problems or having unusual service needs.

Thus, the automated FSS system would be able to serve pilots at many levels in a manner and with equipment suitable to them, while at the same time operating without the very large number of stations and personnel required under the present manual system.

9.3.2 System Description

If any part of the FSS operation impinges on the tower operation, it would be the filing of flight plans. In the manual system, a pilot files his flight plan with a Specialist at a Flight Service station, who then sends it via Teletype to the ARTCC. In the automated system, on the other hand, the services of the Specialist will no longer be needed routinely; the pilot will enter his flight plan through his terminal into the FSS hub computer, which will transmit it to the appropriate ARTCC.

The simplest device available to the pilot would be the touch-tone telephone. A protocol, or encoding scheme, is available which will allow simple, strictly-formatted messages to be entered in a form which can be interpreted by the computer. Responses to the pilot would come as synthesized speech through the telephone earpiece. At another level of complexity, there would be a TV adapter terminal consisting of a device which attaches the home TV set in much the same way that electronic games are attached. This terminal would use the same touch-tone keypad for data entry but would supply output as characters and graphics on the TV screen. Both of these devices could be owned by the pilot and used from the home.

More complex devices will be made available for purchase by larger users and for semi-public use by others. These will have extensive keyboards, both alphanumeric and special function, high-quality display tubes, hard-copy output of both printed material and graphics, and enough processing capability and storage to provide message composition assistance, editing functions, message recall, fixed-data storage, etc.

Each terminal would communicate with a hub computer by telephone, and each of the twenty hubs would be connected to its co-located ARTCC, adjacent hubs and a central Aviation Weather Processor. For flight plan filing, only the terminal-hub-ARTCC path is important.

9.3.3 System Integration/Interfaces

The FSS automated system as described above does not interface directly with the tower cab or tower systems. However, when and if the TIPS program approaches implementation, it will be necessary to examine the possibility of an interface between FSS and TIPS. Since the Flight Data data base may well reside in the data processor in the terminal area, it may make sense to enter the flight plans at that point rather than have them relayed at the ARTCC.

The automation of Flight Service Stations is not expected to have a direct effect on the equipment and duties of tower cab personnel. The interphone communications with FSS's will very likely be unchanged or slightly easier because of fewer FSS's to contact--a few hubs rather than numerous stations. Should some pilots have objections to the self-briefing and filing services, they might request the tower to relay their flight plans, thus increasing the workload for the Flight Data and Ground Control positions.

Many FSS's will be closed down as automation proceeds. At those locations where the FSS now makes the regular weather observations, this function may be transferred to the control tower, with additional duties for the Flight Data position and the additional space requirements associated with weather data displays, particularly the ceilometer device. An alternative arrangement is to install an automatic weather observing system at the location, which will entail a remote display unit in the tower cab but will relieve the tower personnel of the responsibility for preparation and dissemination of the weather messages. Current strategy for deployment of Aviation-Automation Weather Observing System (AV-AWOS) is to install it all airports losing an FSS and having no tower. However, should AV-AWOS prove cost-effective, it could have a wider deployment and might eventually relieve additional towers of weather observing responsibilities independent of FSS closing.

9.3.4 Failure Modes

The automated Flight Service Station is not part of a critical real-time system which requires extensive back-up. Flight plans would presumably need to be filed and the natural paths would be through the FSS Specialist, who would enter them manually through his TTY to the ARTCC, and the Flight Data position in a tower, who would use his FDEP (or TIPS keyboard). Clearly, these failure provisions would only work for a very short time before collapsing under the load.

9.3.5 System Status

Flight Service Station automation will proceed in stages. The end-product of the first stage will be called Model I and will consist of a streamlined version of present-day service. Many small improvements in technique and procedure wil be implemented to produce a better overall product. These changes should be operational by October 1979 according to present schedules.

Module II will be a major change in the form of the system since all FSS's will be closed, to be replaced by twenty hub facilities co-located with the ARTCC's. These stations will contain computers which will supply automated service to the Specialists who will talk to pilots by telephone or radio. The hub computers will be connected to the Aviation Weather Processor, a single FSS facility which accepts information from the National Weather Service computer and pre-processes if for use in the hub computers. In addition, adjacent hub computers are interconnected to provide redundant communications paths within the system. Model II will supply both pre- and in-flight weather briefings and VFR/IFR flight plan filing. Ancillary services, such as airman's testing, will be dropped.

Implementation of Model II at the twenty centers is scheduled for completion by March of 1982; funding has been approved by FAA for facility construction, equipment procurement, and station consolidation. The specifications for this phase were issued some time ago but then withdrawn for rewriting in the face of a great deal of negative comment. No reissue date is available at this time. Meanwhile, the Aviation Weather and NOTAM Service (AWANS) center at Atlanta is serving as a prototype for Model II.

The final version of the automated Final Service Station system includes pilot self-briefing and automated flight plan filing and eliminating the specialist from the process except when called upon by the pilot for assistance. Model III is scheduled for implementation in January 1983.

9.3.6 Issues and Comments

Unless it comes to pass that TIPS is fully implemented and a communications link is set up between the FSS hub computer and the TIPS TRACON computer for flight plan filing purposes, there will be no interaction between FSS automation and the Tower Cab systems. Even if such an arrangement were planned, the impact of either system on the other would be very slight, since the interfaces between them would probably be made identical to the already planned FSS/NAS and TIPS/NAS interface.

REFERENCES FOR SECTION 9

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2. FAA, Specification: Automation Equipment, Requirements for Automated Air Traffic Control Systems, FAA-E-2591a, 1 July 1976.
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7. Rossiter, S. et al., The Controller/Computer Interface with an Air-Ground Data Link, Vols. I & II., FAA-RD-75-133, I & II, September 1975.
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10. WEATHER-RELATED SYSTEMS

10.1 INTRODUCTION

This section describes three weather-related systems within the Major System Development Programs:

1. Vortex Advisory System (VAS)
2. Wake Vortex Avoidance System (WVAS)
3. Wind Shear Detection System (WSDS)

The VAS system has completed developmental testing at Chicago O'Hare Airport. At present (October 1977) it is scheduled to begin operational testing at over ten airports in December 1977. The WVAS is an advanced wake vortex avoidance system, intended to operate with other MSDP systems so as to allow approach spacings under 3 miles. It is presently in the design state, being based upon VAS and advanced sensors that are substantially developed.

Several approaches are being pursued in the development of a Wind Shear Detection System, and a low level wind shear alert system, based on available anemometers, is scheduled for operational test in 1978.

For each of these systems the following sections will, first describe the system as presently envisioned in the 1985-1990 period, second, delineate its interfaces with other MSDP elements and with the remainder of the 1985-1990 ATC system, third describe its backup and failure modes, and fourth, give its present status and deployment plans.

10.2 VORTEX ADVISORY SYSTEM

10.2.1 Introduction

The intensity of the vortices shed from the wings of an aircraft is proportional to the lift generated by the wing. The advent of heavy transport aircraft, therefore, has increased substantially the severity of the wake vortex problem. If the current 3-engine jet fleet is replaced by wide body aircraft having similar field length requirements, the fleet mix can be expected to continue to move toward heavy aircraft with the associated wake vortex hazard.

As the wake vortex problem emerged the FAA found it necessary, in March 1970, to increase IFR separations behind heavy jets (300,000 lb GTOW) to 4 and 5 miles on landing and to at least two minutes on departure. In November 1975, the standards were revised upward once again. Aircraft are divided into three groups on the basis of maximum gross take-off weight; small, large, and heavy.* The major standards for successive single-runway arrivals under radar control at present are given in Table 10.2-1.

The FAA separations given above apply under all weather conditions. In fact it has been discovered that a moderate wind will reliably remove the vortices from the path of the following aircraft.[1,2,3] A wind-rose criterion can be used to determine when the separations of Table 10.2-1 could be reduced uniformly to 3 n mi for all arriving aircraft types. The VAS is a set of wind sensors and displays that indicate to the tower and TRACON when such a reduction is possible. It also provides runway-specific wind information for relaying to pilots and for use in runway selection, although this feature is not presently employed in the VAS operational tests.

The following description of the VAS is based on the R&D prototype system being tested at ORD (from June 1976 to June 1977), but without the Ground-Wind Vortex Sensing System (GWVSS). These auxiliary sensors are designed to detect the presence of the ground component of trailing vortices and serve as a check on the predictive information provided by the VAS deployment.

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*Small aircraft were defined as those with 12,500 lb or less GTOW; heavy aircraft are those with 300,000 lb or more GTOW. All other aircraft are large.

TABLE 10.2-1. CURRENT SEPARATION STANDARDS FOR SUCCESSIVE ARRIVALS (NMI) AT A SINGLE RUNWAY

Leading Aircraft / Following Aircraft	Heavy	Large	Small
Heavy	4	3	3
Large	5	3	3
Small	6	4	3

Notes: (1) Standards apply to aircraft under radar surveillance and when less then 40 miles from the antenna.

(2) Ref: FAA Order 7110.65 Sections 740 and 1420; January 1976.

10.2.2 Description of VAS

The VAS consists of a Meteorological Subsystem, including towers, wind sensors, and tower communications; a Microprocessor Subsystem, which includes processors for the meteorological data and for the VAS algorithm; and a Display Subsystem, comprising a runway display for the controller, a system status display, a maintenance display, and a recording capability. A functional description of these subsystems follows, and detailed specifications are given in Appendix B. Figure 10.2.1 is a functional block diagram of the VAS system as it is presently planned for deployment in the latter part of 1977. This system will now be described.

Meteorological Subsystem

1. Meteorological Towers

The VAS contains a network of instrumented meteorological towers whose signals are transmitted to a centrally located processor which uses a simple algorithm to determine whether wind conditions will allow vortices to persist and then displays this information to the controllers. The tower network consists of seven 50-foot meteorological towers positioned to measure the wind close to each operating corridor. A network of towers is required since the inhomogeneity of the atmosphere precludes the use of a single centrally located sensor for the measurement of wind. The towers are free standing on a cement base and are marked and lighted according to FAA Advisory Circular 70/7460-1.

2. Meteorological Sensors

Each tower is instrumented with three wind speed and direction sensors, one at the 50-foot level and the other two at the 47-foot level. The 47-foot sensors are mounted on opposite sides of the tower to provide a measurement undisturbed by tower shadowing. The wind speed sensor (Bendix Aerovanes) has the following specifications: range of 0-100 knots, accuracy of ±0.5 knots or 2 percent, threshold of 0.75 knots maximum, and a distance constant of 8 feet. The wind direction sensor (vane) has a range

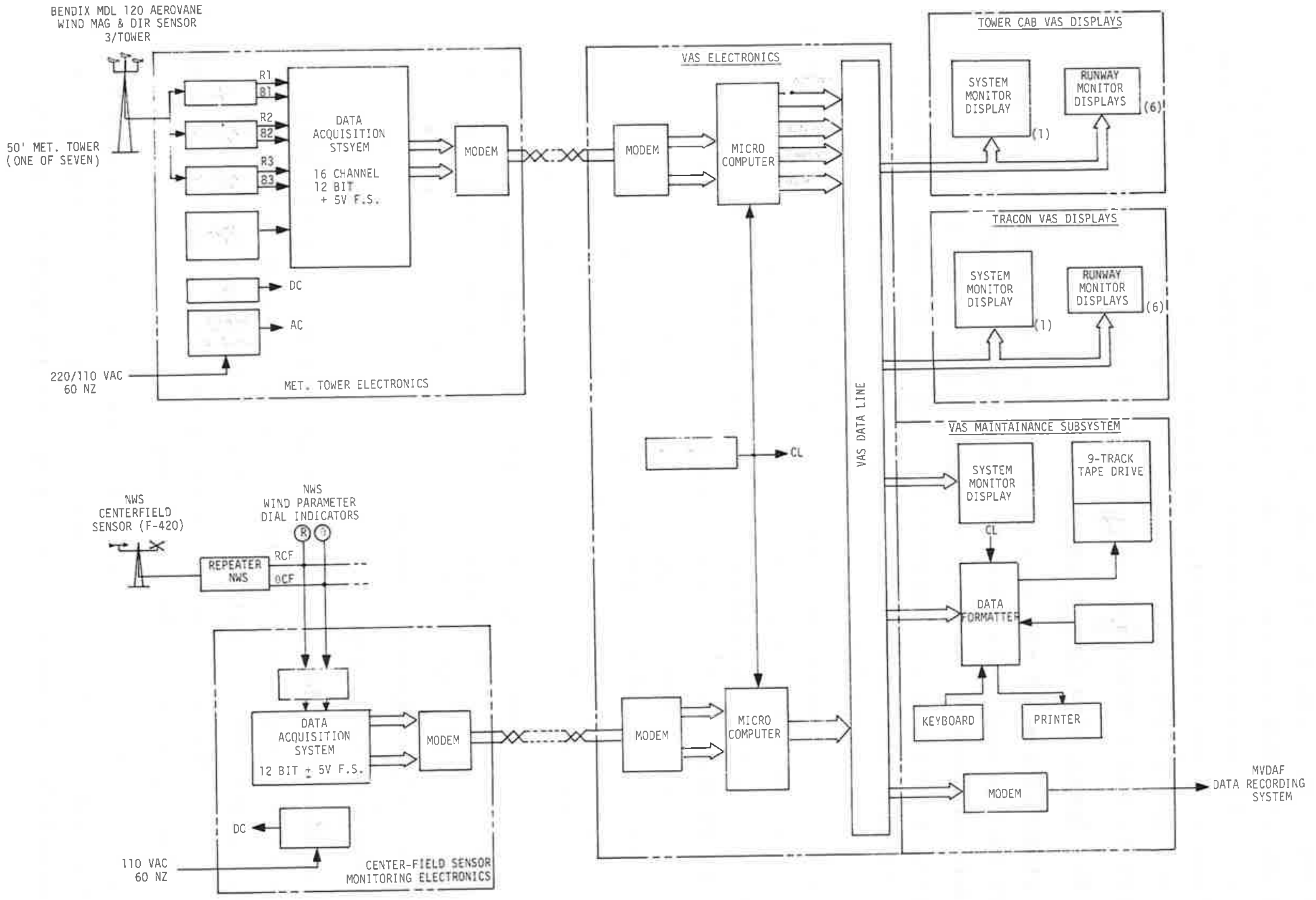

FIGURE 10.2-1. BLOCK DIAGRAM- VORTEX ADVISORY SYSTEM- O'HARE INTERNATIONAL AIRPORT

of 0-360°, accuracy of ±2 percent, threshold of 0.75 knots maximum, distance constant of 30 feet, and a damping ratio of 0.4-0.6. All sensor and communication electronics at each tower are housed in an environmental enclosure. Each tower is supplied with a 220/110-volt, 60-Hz power source, a 2-kVA line-voltage regulator, and a transient arrester for lightning protection.

3. Tower Data Communication

Transmission of the data from the set of widely dispersed towers to the centrally located processor is accomplished with standard hardware. As shown in Figure 10.2-1, the VAS block diagram, a multiplexer successively samples the sensor outputs and converts them to a parallel digital word which is serialized and transmitted over standard existing FAA control lines to a central facility where receivers reconvert the data to a parallel format for input to a microprocessor. A 16-channel, 12-bit data acquisition system sequentially scans the sensor outputs and converts them to a 16-bit word consisting of a 4-bit address and 12 bits of data. The multiplexer operates under the control of a transmitting modem which commands the channel scan, converts the output data to serial format, and transmits the data to a receiving unit where the data are reconverted to a parallel format.

The high channel capacity, resolution, and sampling rate are in excess of what is required. The intent of the overdesign is to allow for expansion of the system without costly and time consuming field equipment changes.

Microprocessor Subsystem

Individual microprocessors are used to process the data received via a signal wire pair from each meteorological tower. The microprocessors contain 8K of Read-Only-Memory and 8K of Random-Access-Memory. Each microprocessor is packaged on a single plug-in board, an Intel Model SBC 80/20.

The microprocessors sample the meteorological data output from each data receiver at a rate of 2 samples/sec. The sampled wind magnitude (R) and wind direction (θ) are used to compute a one-minute running average ($\overline{R}$ and $\overline{\theta}$) by the following scheme: for each sample compute $V = R\sin\theta$ and $U = R\cos\theta$, compute $\overline{R} = (\overline{U}^2 + \overline{V}^2)^{1/2}$ and $\overline{\theta} = \tan^{-1}(\overline{V}/\overline{U})$.

A wind gust is defined using a 30-second interval. Within each 30-second interval the samples R are averaged using a 4-sample running average. Momentary peaks due to high frequency gusts which would not affect aircraft operations are filtered out by the sample running average. Transient spikes in the data are eliminated by a comparative process. Any measured peak must be at least 9 knots above $\overline{R}$ to be considered a gust. The gust value is the peak value observed during each 30-second interval. At the end of each 30-second interval the gust value is compared to the gust value observed during the previous 30-second interval and the larger of the two is displayed.

The R and θ from the three sensors on each tower are compared after each sampling interval. A sensor failure bit is generated if the R of any sensors differs by more than 3 knots or if the θ of any sensor differs by more than 10°. Normally, the 50-foot sensor data are used for the VAS algorithm. If the 50-foot sensor output fails, the microprocessor switches to the 47-foot sensors and selects the sensor which is not in the shadow of the tower. Failure of at least two sensors to agree terminates all data output from that tower. Upon detection of a failure, a failure word is generated identifying the sensor which failed or, if two sensors disagree, which tower has been shut down.

Each microprocessor also calculates the allowable aircraft landing separations for a runway based on the wind speed and direction measured by the instrumented tower. As shown in Figure 10.2-2, an elliptical VAS algorithm is used which includes a buffer or "transition zone". The major and minor axes of the inner and outer ellipses are 12.5, 14, 6.0, and 7.5 knots, respectively. The transition zone allows for a gradual change between states, as opposed to an abrupt change which an air traffic controller working a line of approaching aircraft could obviously not accommodate.

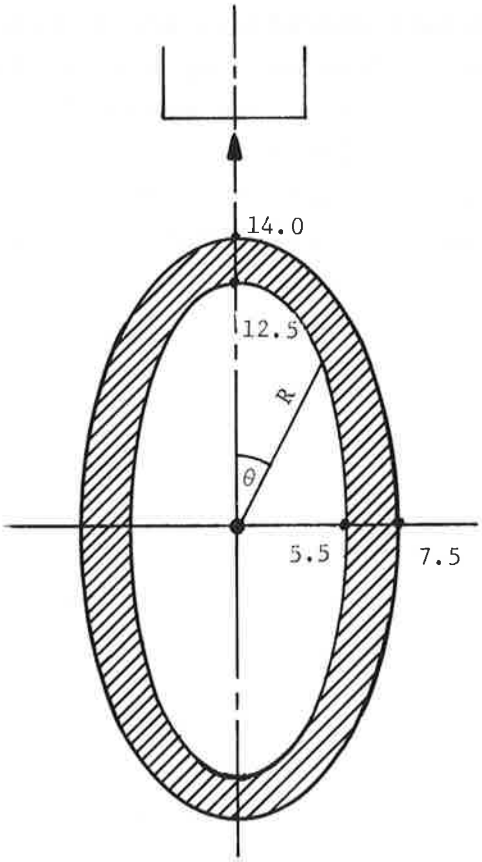

FIGURE 10.2-2. WIND CRITERIA FOR ELLIPTICAL VAS ALGORITHM

If the wind magnitude decreases to the point where the wind vector lies wholly within the inner ellipse, the runway status is changed from green to red. This transition has a safety factor in it,which allows an aircraft which is on final at the time to complete its landing. Following aircraft will have to revert to the 3, 4, 5, 6 nmi. spacing shown in Table 10.2-1. If the red condition exists and the wind magnitude increases to the point where the end of the wind vector lies outside the outer ellipse, then the status is changed to green, but only after the new condition has existed for the period of one minute.

The VAS processor outputs labeled data onto a data bus with the following information for each operating region: $\overline{R}$ to 1 knot, $\overline{\theta}$ to 10°, gust (if applicable) to 1 knot, the vortex condition RED or GREEN for each landing runway, and failure messages.

Display Subsystem

1. Runway Monitor Display (RMD)

The system interfaces with the air traffic controllers via the VAS Runway Monitor Display (Fig. 10.2-3). The controller selects the operating corridor and designates either the arrival (A) or departure (D) runway. The display thereafter accepts data with the corresponding label from the data bus. The controller display provides in digital form the wind direction, magnitude, and gust in the selected region. If arrivals are being handled by the controller, the display indicates whether the vortex conditions require a 3-, 4-, 5-, or 6-mile separation between aircraft (RED) or whether an all 3-mile separation (GREEN) may be used. If departures are being handled, only the wind conditions are displayed and the RED/GREEN indications are blanked out.

2. VAS System Monitor Display (SMD)

The VAS System Monitor Display (Fig. 10.2-4) displays the wind measurements from all towers simultaneously, as well as the Red-Green status of all runways. The display could be used by the

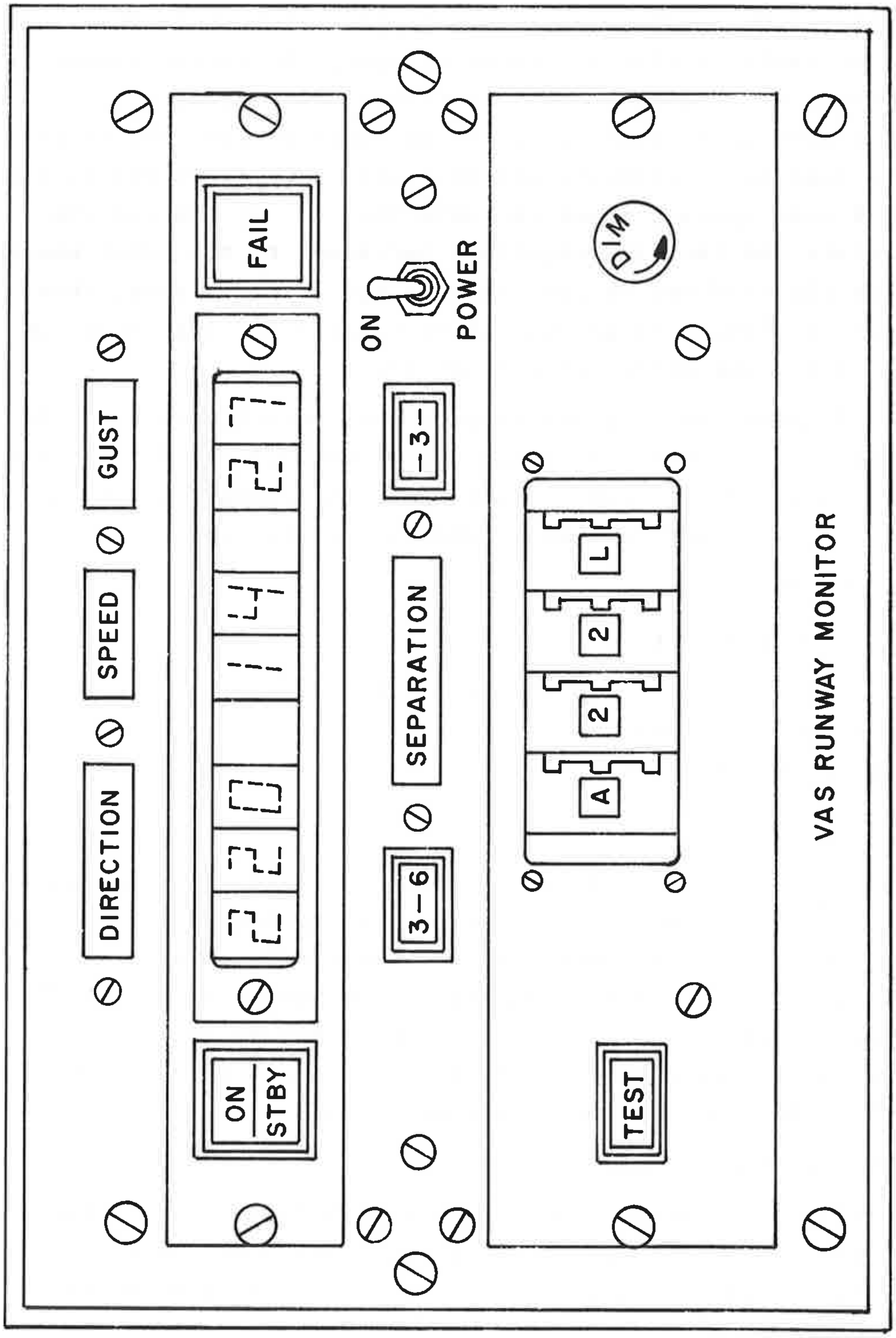

FIGURE 10.2-3 VAS RUNWAY MONITOR DISPLAY

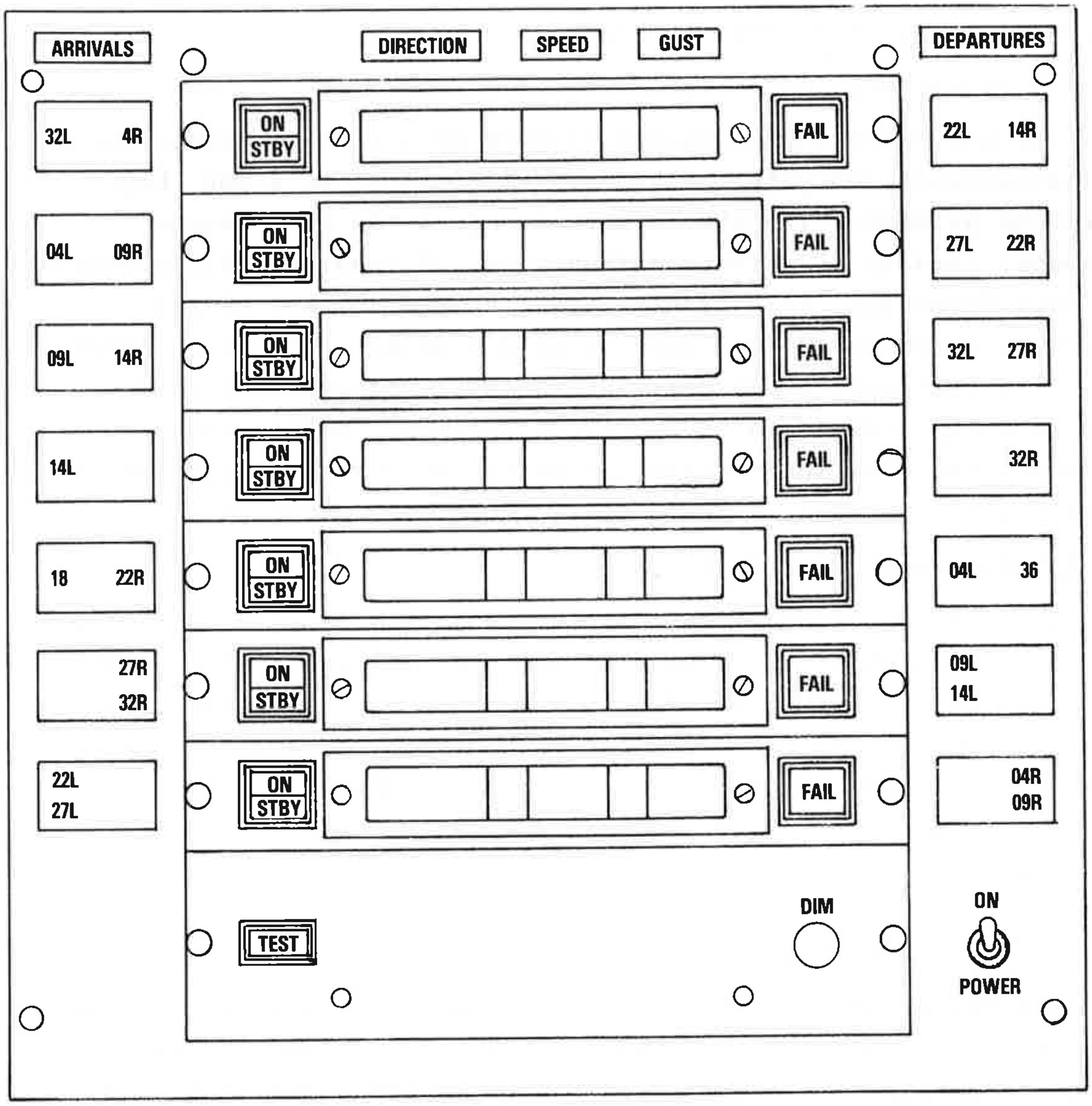

FIGURE 10.2-4. VAS SYSTEM MONITOR DISPLAY

TRACON and cab supervisors to establish operating runway configurations in conjunction with other airport operating considerations or constraints. (See Sections 5.6.2.8-9.)

3. VAS Maintenance Subsystem

The VAS electronics console (Figure 10.2-5) also houses the VAS maintenance subsystem. This system consists of a SMD keyboard and printer. The SMD is used to alert the maintenance personnel rapidly of a tower malfunction. A separate microprocessor, the data formatter, also prints out an hourly summary of all observed system anomolies, such as data dropouts, sensor failures, etc. These anomolies may not cause a tower shutdown but can provide an early indication of impending failure. Maintenance personnel can also interrogate the system at any time, via the keyboard, to obtain a printout of all detected anomolies.

4. VAS Data Recording System

The Data Recording System shown in Fig. 10.2-1 consists of a 9-track digital magnetic tape unit with buffer electronics. All data sent to the VAS Runway Monitor Display, the VAS System Monitor Display, and the VAS System Maintenance Display are blocked and recorded continuously on this unit. The accumulated data tapes are stored for later system analysis and FAA record keeping purposes.

10.2.3 VAS/ATC System Interfaces

The major VAS/ATC interfaces are shown in Figure 10.2-6. As seen in this figure, the VAS, via the VAS System Monitor Display, conveys wind information for all runways to the Tower Supervisor or Cab Coordinator. The Approach Controller dials into the VAS Runway Monitor Display the arrival runway of concern of the aircraft under his control. Thereafter, the VAS Runway Monitor Display indicates to him the appropriate spacing selection. Further, it also gives him wind speed and direction information, and gust speed for the

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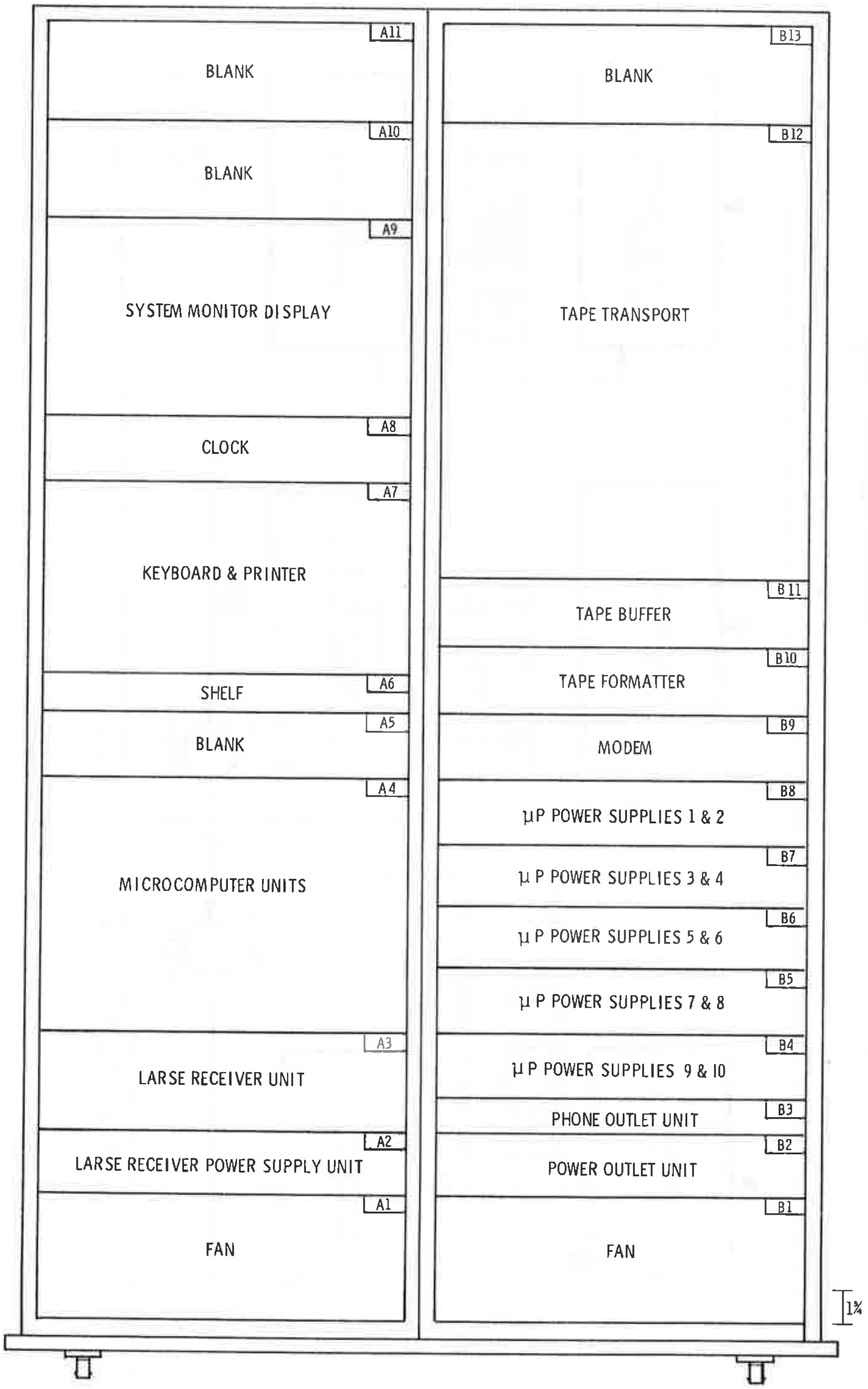
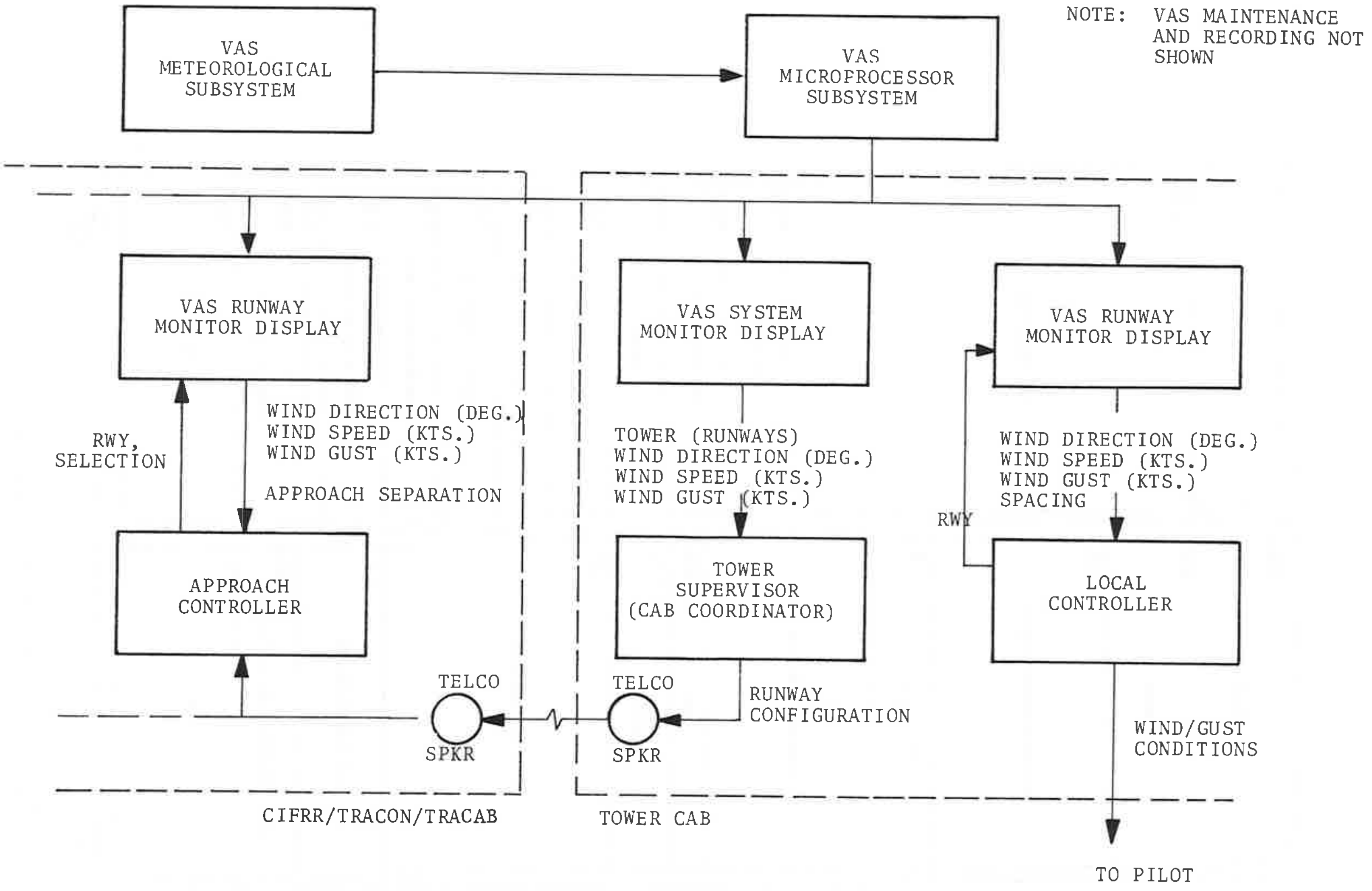


FIGURE 10.2.-5. VAS ELECTRONICS CONSOLE



NOTE: VAS MAINTENANCE AND RECORDING NOT SHOWN

FIGURE 10.2-6. MAJOR VAS/ATC SYSTEM INTERFACES runway of interest. If "D" for departures has been dialed into the unit, no spacing information is displayed. It should be noted that:

1. The VAS does not provide separation information for Departure/Departure, Departure/Arrival or Arrival/ Departure.
2. The VAS provides partial information for three functions not directly concerned with aircraft vortices:
    - Runway configuration selection
    - Pilot wind condition advisories
    - Pilot gust warning advisories.

With regard to runway selection, current FAA Orders (7110.65, para. 960.) specify that except where a noise abatement program is in use the controller shall use the runway that is most nearly aligned with the wind (or the calm wind runway if wind is less than 5 knots), unless the pilot requests another runway, or use of another runway will be operationally advantageous. The runway selection is affected by

wind alignment

noise abatement

pilot request

operational advantages (e.g., capacity)

To this list must be added

wake vortex avoidance

and very possibly

metering and spacing

in the near future.

Once the runway configuration has been selected, the VAS Runway Monitor Display indicates a red or a green condition. If the red light is on, the controller spaces aircraft at 3, 4, 5, or 6 miles, depending on size. With the green light on, all aircraft can be safely separated by only 3 miles. If the red light is on, it will turn to green when the wind vector, as computed in the microprocessor, goes outside of the outer ellipse shown in Figure 10.2.2. If the light is green, it will change to red when the wind vector falls within the inner ellipse. This system is relatively easy on the controller, requiring only that he note the condition for whatever runway(s) he is using and conform with the rules. The light pairs require comparatively little space in the tower, and there is considerable flexibility regarding where they may be located.

10.2.4 VAS Failure Modes

The redundant sensor configuration of the towers allows detection and display of met-sensor failure. The failure status of each tower array is indicated on the controller's display and also in the system maintenance console. Test of the controller's display is provided on the console front panel. This indication is redundant with that on the maintenance console, providing protection against malfunction of either.

In the event two sensors fail on the same tower it would be necessary to extend spacings to 3, 4, 5, or 6 miles on that runway until repair is effected. The effect on ATC operations would pose no safety problem if the failure is promptly detected.

10.2.5 VAS Status and Development Plan

The VAS R&D prototype is undergoing tests at O'Hare from June 1976 through June 1977. This is to be followed by tests of an operational prototype from December 1977 through May 1978. Deployment of the operational VAS is planned for the FY 1979 budget, commencing in October 1978. Of some 15 airports considered initially, 11 have been recommended for the FY 79 deployment. See Table 10.2-2.

The VAS has not been identified as an element of an MSDP distinct from the WVAS. The development plan for VAS therefore has been included in that for WVAS.

TABLE 10.2-2. VAS DEPLOYMENT SITES

ORD	Chicago O'Hare International
DEN	Denver Stapleton International
SFO	San Francisco International
LAX	Los Angeles International
ATL	Atlanta Hartsfield International
MIA	Miami International
JFK	John F. Kennedy International
LGA	La Guardia Airport
BOS	Boston Logan International
DFW	Dallas-Ft. Worth International
DTW	Detroit Wayne County

10.3 WAKE VORTEX AVOIDANCE SYSTEM

10.3.1 Introduction

The MSDP's project substantial improvements in IFR runway capacity due to improved metering and spacing and to reduction of longitudinal separation standards. These improvements are aimed at reducing spacings below 3 n mi. In order to do so, a more refined sensing of wake vortex motion is required than can be provided by the VAS. While under many wind conditions wake vortices normally dissipate more rapidly than required by 3-mile spacing, it is necessary to have a more positive indication of their dissipation if spacings are to be reduced below three miles. Further, the lower spacings should be specified as a function of aircraft pair-type in order to avoid unnecessarily large gaps. The WVAS is based on adding to VAS these two features, namely

1. Positive sensing of ground vortex conditions to augument the prediction based on meteorological tower data,
2. Expansion of the microprocessor to allow calculation of the spacings as a function of aircraft type.

10.3.2 Description of WVAS

System specifications for WVAS are not available at the present time (May 1977). As an approximate description, however, one may take the preceding VAS specifications and add the following:

Ground Vortex Sensors

The ground vortex sensors would determine, for each aircraft landing, the actual vortex dissipation time or time of translation out of the approach corridor. Several sensor types are possible: acoustic doppler, pulsed,or CW laser anemometer. At present, a linear array of anemometers deployed at right angles to the runway appears to be the most likely sensor choice.

The detection of vortices by these sensors is based on the fact that the pressure and velocity fields associated with a low altitude vortex extend to the ground and can be detected by ground-based sensors. The array of anemometers would measure the component of wind perpendicular to the aircraft flight path. Since most of the vortex velocity field is in that direction, the passage of a vortex overhead will cause a large change (increase or decrease) in the ambient cross-wind velocity. In the O'Hare tests, Gill-type single axis propellor anemometers were employed, arrayed with their axes on a line perpendicular to the runway centerline. A fifty-foot spacing between anemometers was used, up to the lateral coverage of interest. At O'Hare, a 700-foot baseline was used, extending ±350 feet to each side of the extended runway center line. Data from these sensors are transmitted to the central location in the control tower equipment room, using a DAS-16 data acquisition module and a LES-111 and a LCR-211 data transmission and receiving unit.

Mini-Computer

One processor must be capable of performing at least the following functions for each instrumented runway:

1. Met tower data sampling
2. Met tower data averaging
3. Tower sensor failure detection

4. Wind speed and direction calculation
5. Gust calculation
6. Ground sensor data sampling
7. Ground sensor data averaging
8. Ground vortex detection
9. Ground vortex motion calculation
10. Ground sensor failure detection
11. Calculation of ground vortex motion and wind information
12. Aircraft type data acceptance and checking
13. Spacing calculation
14. Warning check
15. Outputting of spacing information to Metering and Spacing System.

In addition to the runway-specific functions above, the processor must also output system status information, including sensor failure status.

10.3.3 WVAS/ATC Interfaces

A very general diagram of the WVAS/ATC Interfaces is given in Figure 10.3-1. At present the WVAS/M&S interface is in the process of definition by FAA/SRDS and DOT/TSC. The present WVAS/M&S concept requires spacing to be adjusted as a function of aircraft type, wind conditions, and actual vortex sensing. The last factor would serve as a check on the wind condition information, only rarely requiring aircraft go-round. Present plans have not yet allowed for other than arrival-arrival spacing. The arrival-arrival spacing would be set into an aircraft type matrix by the WVAS processor and transmitted to the ARTS III computer Metering and Spacing computation. The resultant M&S instructions would be conveyed to the pilot by the approach controller or DABS/Data Link.

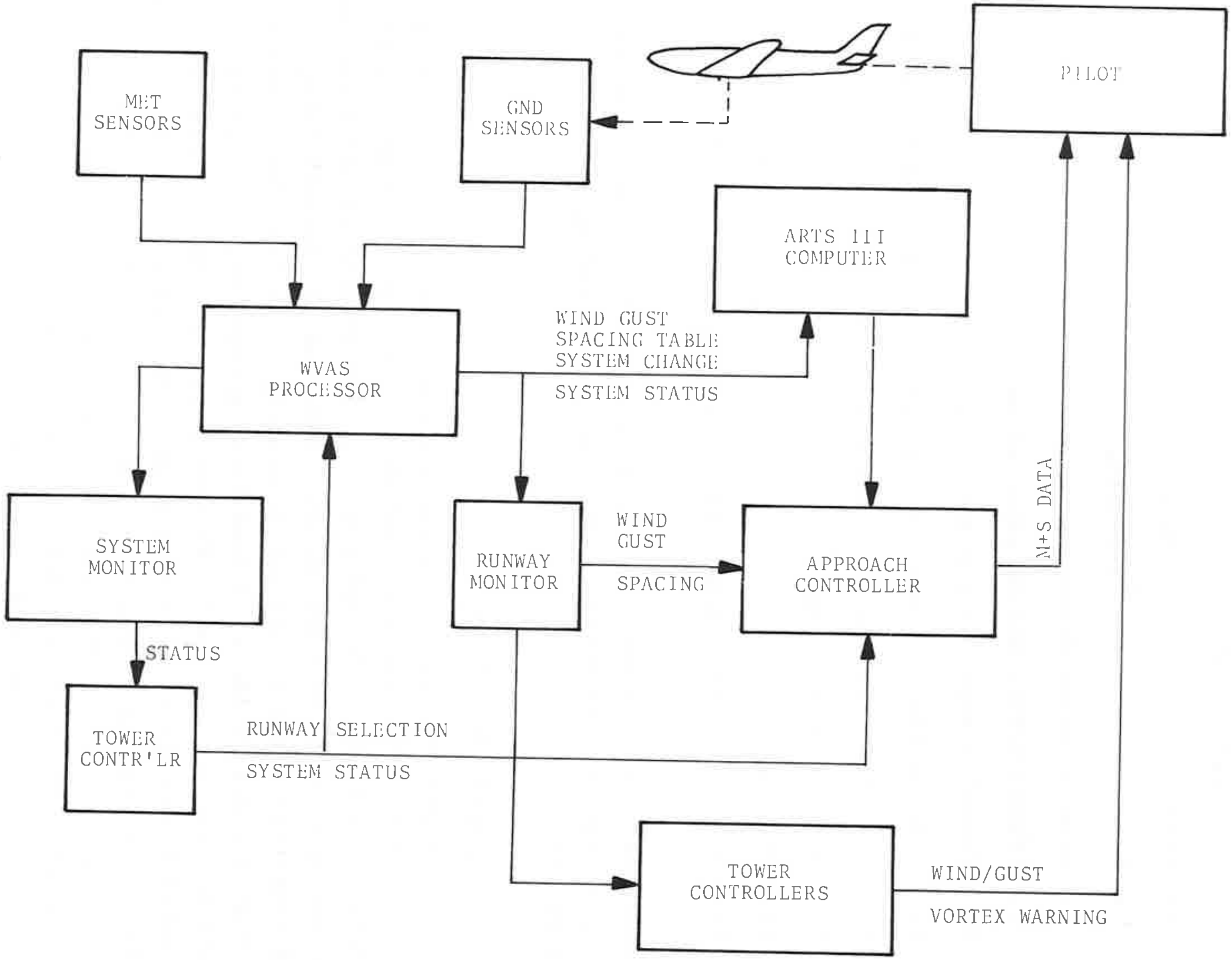


FIGURE 10.3-1. PRELIMINARY WVAS/ATC INTERFACES

10.3.4 WVAS Failure Modes

It is probable that WVAS failure detection for meteorological sensors, microprocessors, and displays will resemble that for the corresponding parts of VAS. If an acoustic doppler or laser system is incorporated, however, special failure detection for that device may be needed. This may take the form of (1) redundant instruments, or (2) automatic self-test, or (3) consistency tests performed in the microprocessor on the signals received from the separate sensors.

As in the case of VAS, a failure of the WVAS should revert the system to the 3-, 4-, 5-, or 6-mile spacing rule, without serious degradation of safety. Also, a failure in the WVAS could cause the system to revert to a VAS.

10.3.5 WVAS Status and Development Plans

The WVAS Program Plan is currently being rewritten and will be available in late (calendar) 1977. A tentative schedule with milestones is given in Figure 10.3-2.

10.4 WIND SHEAR DETECTION SYSTEMS

10.4.1 Introduction

The wind shear hazard, unlike that of aircraft wake turbulence, occurs only under special meteorological conditions. These conditions are relatively rare; the time that strong wind shears may be encountered at an airport is perhaps 100-200 hours per year.[4] While the impact on air delays thus has been minimal, the impact of wind shear on air safety has been notable. Several accidents and numerous incidents have been recorded since the early 1970's. In most of these incidents, one of two effects were manifest: (1) a sudden increase in headwind, (or decrease in tailwind) resulting in increased lift and elevation of the aircraft above its planned flight path, or (2) a sudden decrease in headwind (or

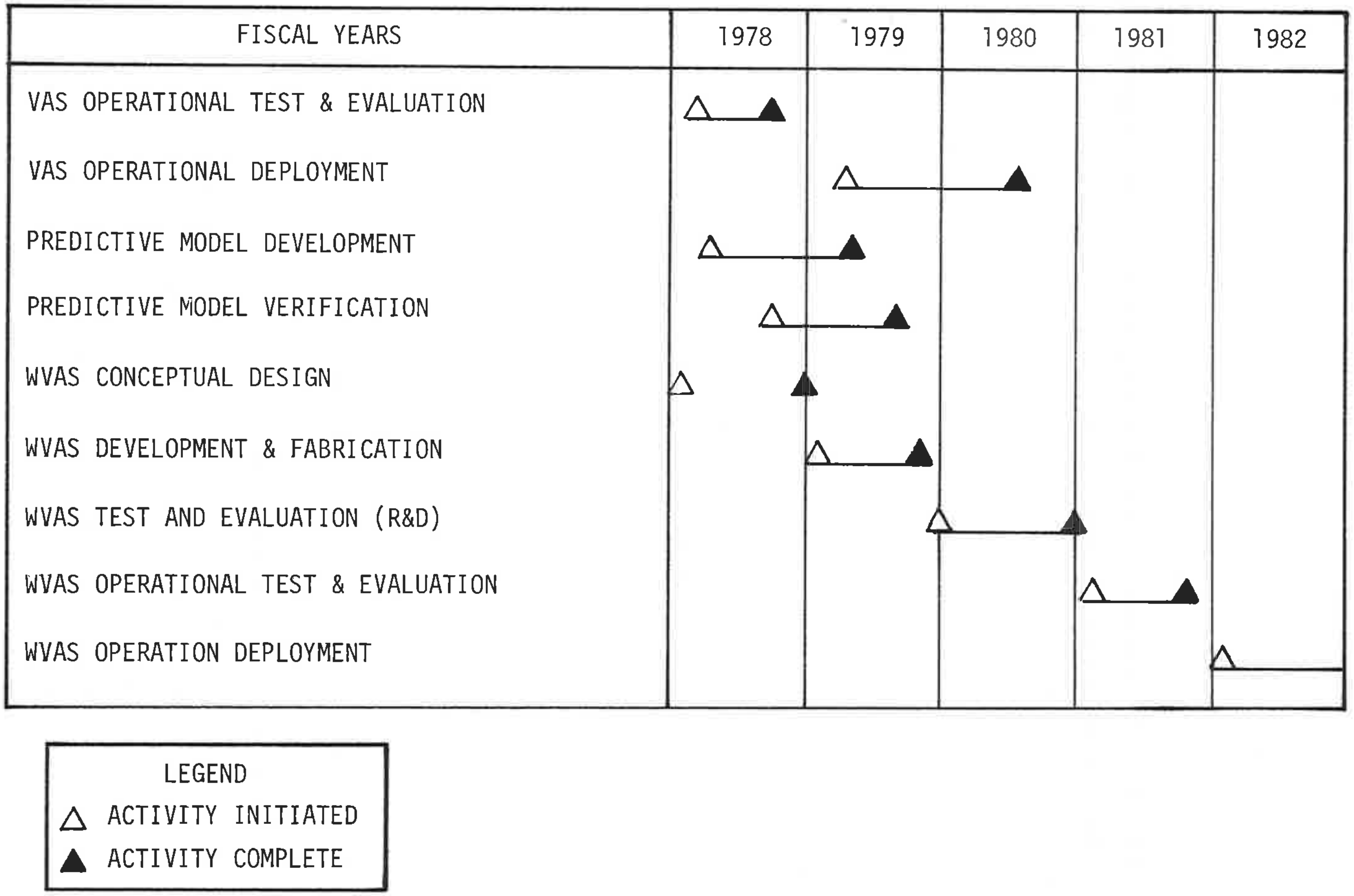


FIGURE 10.3-2. SCHEDULE AND MILESTONES WAKE VORTEX PROGRAM

increase in tailwind) resulting in a reduction in lift and depression of the aircraft below its intended flight path. While the former condition may cause a missed approach on landing, the latter can result in ground collision if it occurs just before touch-down or after take-off.

It has become clear, however, from such accidents as that at Denver Stapleton Airport (1976) that downburst cells are also a significant factor in the wind shear hazard, and in fact are a prominent cause of the headwind/tailwind effects described above.

Wind shear generally occurs in connection with one or the other of three meteorological conditions: These conditions, in order of severity, are discussed below.[4]

Gust Fronts. Gust fronts are normally formed from mature, severe thunderstorms and can be extremely hazardous to air traffic when located in the vicinity of airports. A zone of maximum hazard precedes the radar echo and is not identified by current airport surveillance radars or adequately detected by today's airport weather sensors. Only on very rare occasions has it been located and tracked by weather radar. It is usually determined after the fact by analysis of airport surface weather observations and pilot reports. It is seldom mentioned in terminal forecasts issued by the National Weather Service. The gust-front phenomenon has a maximum occurrence frequency which is coincident with the maximum thunderstorm frequency.

Fast-Moving Frontal Zones. The second mechanism capable of causing strong wind shears are fast-moving frontal zones. These fronts are routinely identified by conventional meteorological analysis. However, identification of the shear zones is much more difficult. Throughout the continental U.S., there exists a relatively meager network of 150 upper-air observing stations. They routinely collect data twice a day at 12-hour intervals. To determine the winds immediately near and over the collection site requires tracking a balloon located in the low-level wind field. Over the first 1,000 feet above the tracking site, if winds are not too strong, only two low-level wind measurements are usually obtained, one at 500 feet and one at 1,000 feet. Often when the type of winds that cause hazardous shear are present, an accurate measurement of the wind, other than the surface winds, is not possible for any level of concern for most wind shear hazards. Hazardous wind shears associated with frontal movement typically reach a maximum frequency between late Fall and early Spring.

Low level Inversion. The last meteorological condition that creates wind-shear hazards, and perhaps the rarest of all, is the condition where a low-level temperature inversion forms near the surface with a warmer, low-level wind of considerable magnitude immediately on top of the inversion. This situation typically occurs early in the morning around sunrise.

To summarize, hazardous low-level wind shear can be generally characterized as a rare event that is not easily tracked or predicted. It occurs year-round, and when detected it is normally after the fact, by ground instrumentation or through the pilot warning system.

10.4.2 Possible Wind Shear Detection Systems

No Wind Shear Detection System has been selected or designed for future installation. At present it is possible only to describe in general terms several possible systems undergoing research and development.

I. Ground-Based Anemometer System

In October 1976, the FAA decided to deploy a service test and demonstration wind monitoring system at six airports. The system is presently in a research and development phase.It is designed primarily to detect wind shear associated with thunderstorm gust fronts. A secondary aim is to facilitate implementation of the VAS at those airports where VAS is being considered for implementation. A third objective is to provide the ATC system and pilots with wind data that are more representative of conditions at the approach and departure ends of the runways than is provided by "center field" wind measurements. It should be noted that, by FAA Order 6560.3A, all wind information for an airport must be derived from a single unit located "as near as possible to the average lift-off positions on the main runways." This point is referred to as "center field", but may be located substantially away from the gometric center of the field.

The ground-based anemometer system is still undergoing development. The current version, the Low Level Wind Shear Alert System (LLWSAS) is described here. It is expected that changes to the system as described here will take place as development proceeds.

Low Level Wind Shear Alert System (LLWSAS)

The intent of the LLWSAS is to utilize additional anemometers on 20-foot towers around certain airports to detect propagating wind change zones that intersect the ground. LLWSAS is designed to detect horizontal winds associated with cold fronts and thunderstorm gust fronts. It will not detect elevated fronts such as warm fronts aloft, nor will it give information on vertical wind profiles. Finally, although it will not give any information along the flight path, per se, wind shifts observed at the surface can often be inferred to exist several hundred feet aloft. Figure 10.4-1 is a diagram of the present LLWSAS concept.

The anemometers will have dynamic characteristics similar to the existing centerfield National Weather Service anemometer (F420C). They will be located in open, flat terrain along high use center-line axes far enough away from touchdown points so that adequate warning can be given to a pilot of an approaching wind shift zone before the pilot crosses the approach decision-height point (ILS middle marker). Anemometers will also be located away from existing center lines if it is necessary to cover those quadrants of the airport not intersected by a runway axis. The current test system employs five remote anemometers each located on a 20-foot tower. The number to be employed in future installations will be based on a review of system performance.

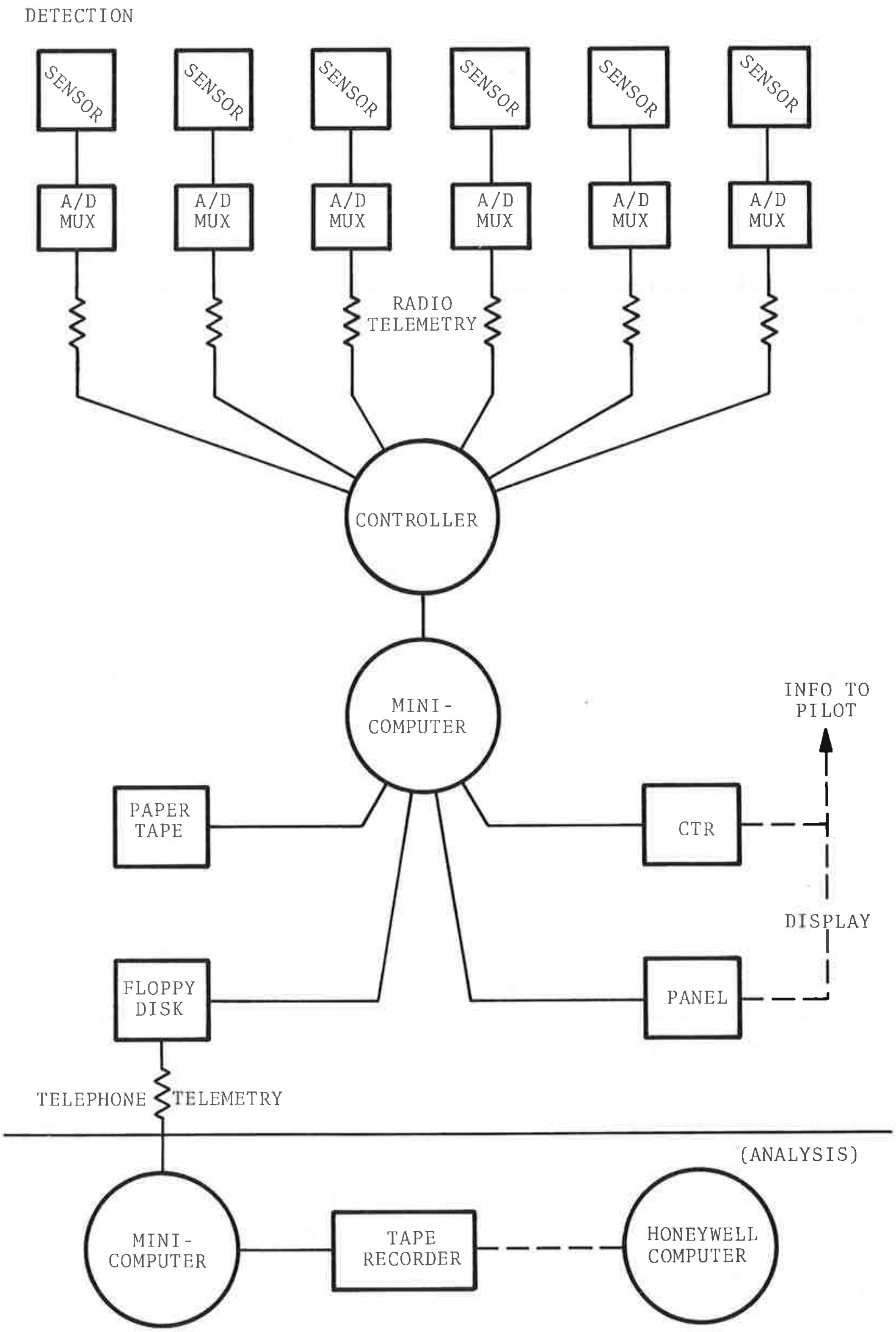


FIGURE 10.4-1. LOW LEVEL WIND SHEAR ALERT SYSTEM

In evaluating LLWSAS, special attention will be given to determining whether the location planned for the remote anemometers is adequate. Wing tip vortices generated by low-flying aircraft and terrain obstructions usually prevalent around airport boundaries, should not be allowed to significantly affect the wind output (to the extent that anomolous and short-lived wind bursts trigger the wind shear alarm). It may become necessary to relocate wind sensor sites if non-meteorological "noise" unduly affects the system.

LLWSAS is a realtime, computer-controlled, data acquisition, analysis, display and recording system. As such, it partially fulfills the need for mesoscale meteorological interpretation presently unavailable. It takes the wind speed and direction data that are received from the remote anemometers and compares these data with the centerfield anemometer output. Wind vector differences are computed between each remote anemometer and the centerfield anemometer (CFA). If the vector difference is large enough (currently 15 knots) it will be interpreted to mean that a significant horizontal wind shear is present which might be hazardous to aircraft operating in the terminal zone. If a significant wind shear condition is detected LLWSAS alerts the Air Traffic Controller by displaying the wind speed measured by the anemometer that caused the alert on a digital display located in the tower cab, accompanied by an audio alarm of about 1-second duration. A preliminary layout of the display is given in Figure 10.4-2. Each line of this display is devoted to one of the sensor towers. Pressing the button to the left of the character-line displays the direction and speed of the wind at the sensor assigned to that line. When a significant shear occurs the direction and speed information is flashed on the appropriate line, accompanied by the audio alarm, without controller action. Gusts are not currently displayed since filters installed at each remote site tend to remove the gust information.

When the alarm is received, the tower controller will provide pilots with an advisory which inculdes the centerfield wind plus the remote site location and wind information that is displayed.

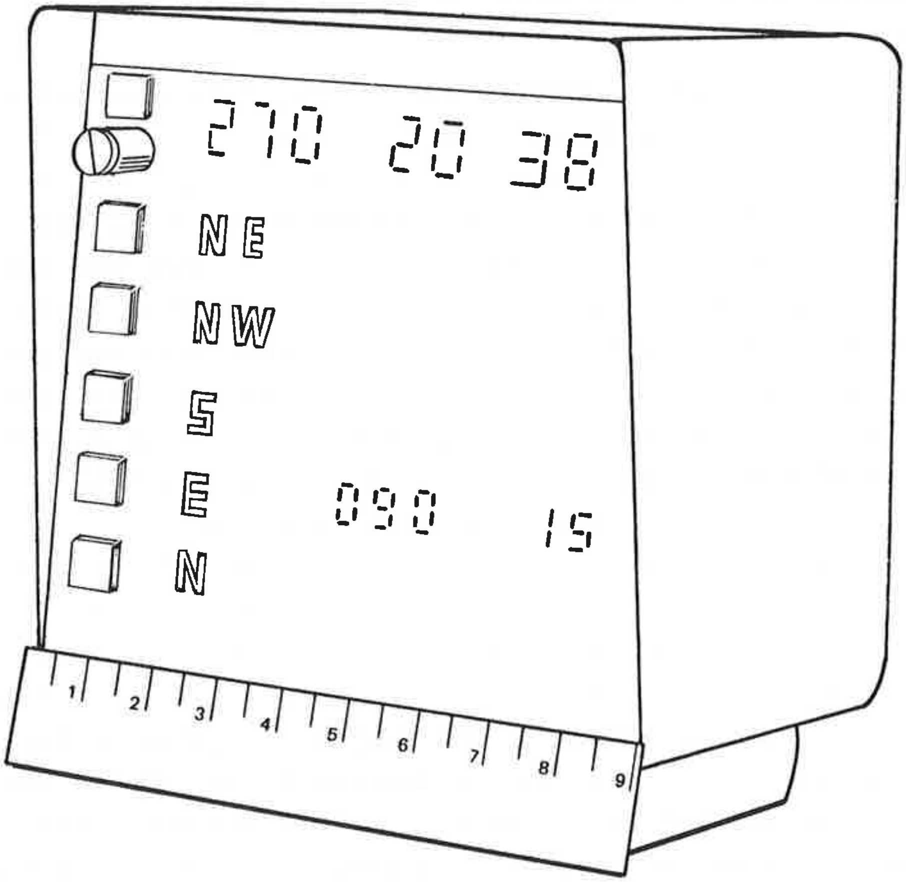


FIGURE 10.4-2. EXPERIMENTAL DISPLAYS FOR LLWSAS

The system will have the capability of continuously displaying wind data from any or all remote sensors when manually selected by the controller. However, this capability will be initially inhibited, through either software or wiring, on an individual sensor basis.

The raw sensor data are also recorded on a flexible magnetic storage device (Floppy Diskette) for later analysis to verify wind shear thresholds, determination of optimum gust factors, correct location of remote anemometers for adequate warning, adequacy of averaging techniques, screening techniques to eliminate effects of wing-tip vortices and terrain obstructions, and reliability of sensors and electronic hardware in adverse weather.

The present experimental LLWSAS hardware shown in Figure 10.4-3 will be located remote from the cab operating area, probably in an adjacent equipment room. The previously described digital display will be located in the cab at or near the local controller.

II. Gust Front Warning System (GFWS)*

1. Pressure Jump Sensors

Goff and others have identified three meteorological parameters that accompanied each gust which he investigated. In the order of occurrence, they were: a pressure increase (but not necessarily a jump), a wind shift,and a temperature discontinuity drop.[5] With that sequence of events in mind, the FAA sponsored the development of a comparatively simple detection technique called the Gust Front Warning System (GFWS), consisting of arrays of pressure-jump sensors (PJS) strategically deployed on and off an airport. Test systems have been installed at the Chicago O'Have airport, at Dulles International airport and near the NSSL WKY-TV meteorological

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*The description of the GFWS here given is taken from Reference (6).

FIGURE 10.4-3 LLWSAS HARDWARE

tower. The O'Hare system, which was removed in September 1977, consisted of 18 PJS's deployed as indicated in Figure 10.4-4. Each PJS is calibrated to send a coded signal via a leased telephone line to a central data recording and test display console located in the base of the O'Hare control tower. A signal is sent when a pressure rise of 0.5 mb in 120 seconds is equaled or exceeded at any site. A much denser array of pressure jump devices, designed to evaluate the same phenomena, is installed at Dallas (Figure 10.4-5).

2. Vertical Scanning Probes

Coupled with GFWS at Dulles, and primarily used for the detection of frontal and inversion related shear, is a vertical scanning probe. Two devices are currently candidates for further development in this area. One is the dual sensor acoustic Doppler radar and complementing pulsed EM Doppler radar which has been installed for testing at Dulles. Together they form a dual vertical profiler system for all-weather detection of wind speed and direction in 30-meter increments from about 30 to the 500-meter level.

The requirement for the pulsed Doppler radar results from the fact that the acoustic radar does not detect wind shear properly during periods of moderate to heavy rainfall due to noise interference. The pulsed Doppler will automatically take over detection when that happens. The Dulles acoustic system is perhaps the most advanced of its kind anywhere. Several commercially available acoustic sounders were tested for the FAA by TSC and WPL in 1975 and 1976. All of them suffer from the same problems, the inability to accurately measure winds in sustained noise thereby negating use during peak aircraft activity. Whether the WPL acoustic Doppler system has overcome the problem enough to be operationally useful remains to be seen. A review of development, accuracy, and testing of the dual sensor is given in Beran, et al.[7]

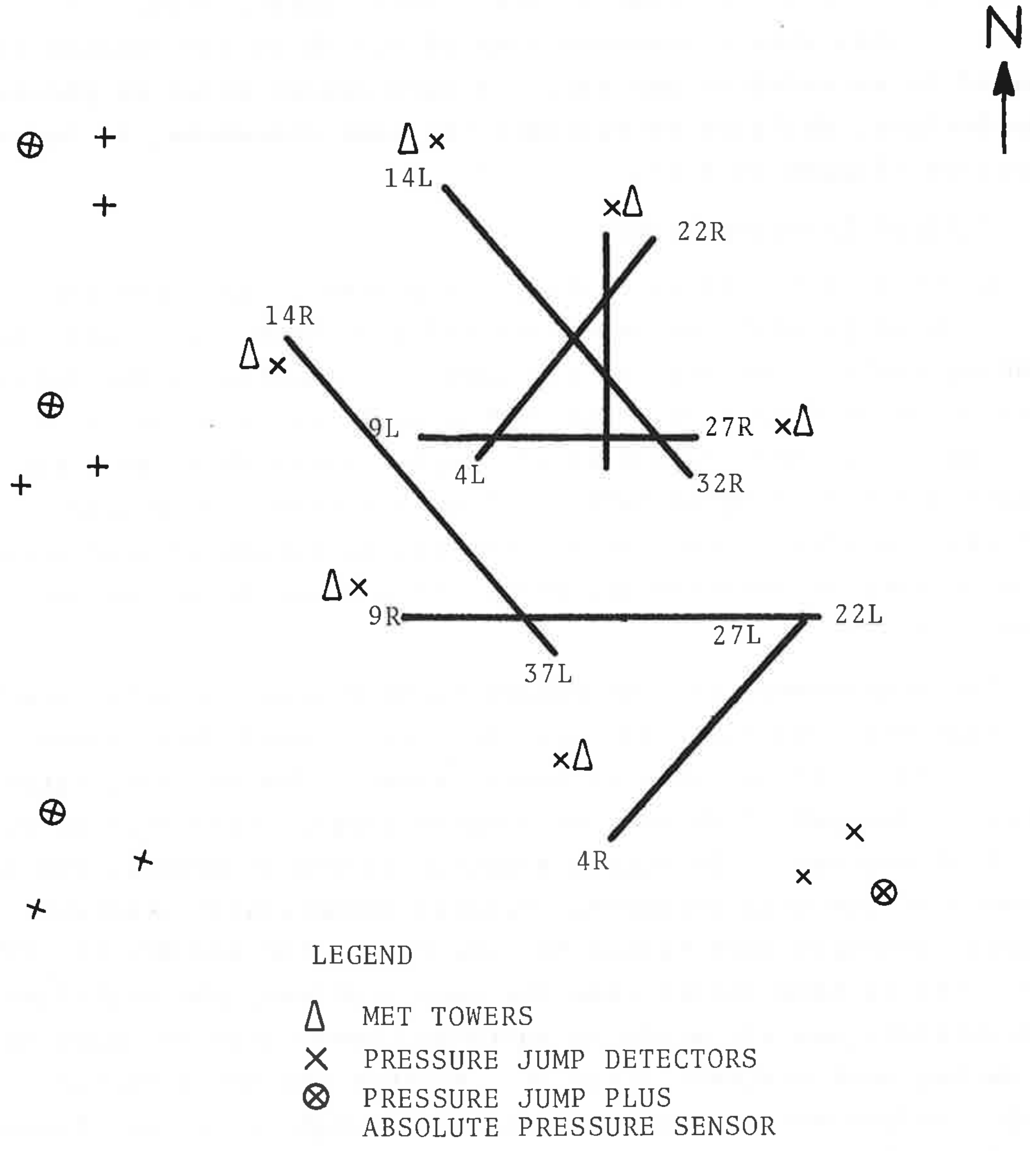

FIGURE 10.4-4. CHICAGO O'HARE GUST FRONT WARNING SYSTEM CONFIGURATION

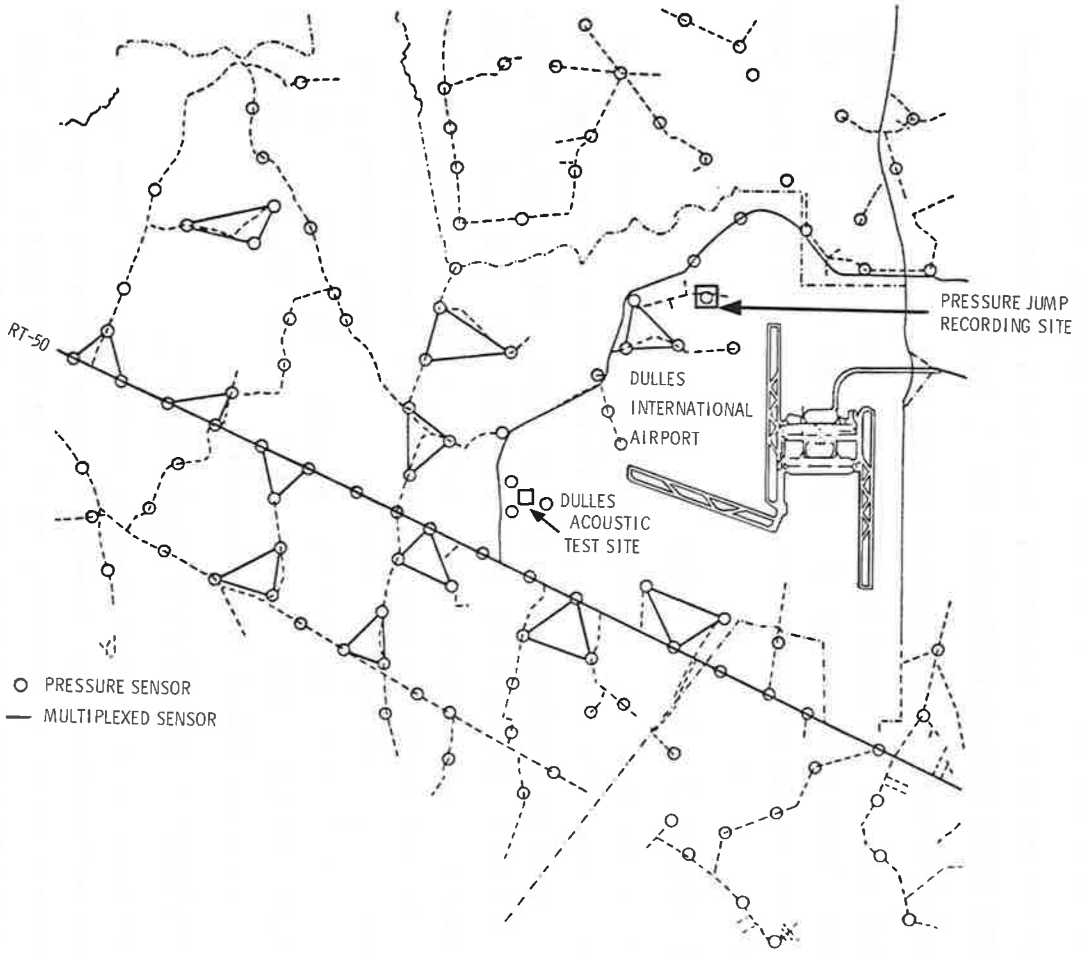

FIGURE 10.4-5. PRESSURE SENSOR INSTALLATION - DULLES INTERNATIONAL AIRPORT

The other candidate for the near term vertical scanning probe for low-level wind shear detection is the Laser Doppler Velocimeter (LDV). Testing of a prototype LDV was conducted at NOAA's Table Mountain test site near Boulder, Colorado against a 152-meter wind tower and NSSL's 450-meter wind towar near Norman, Oklahoma.

The Laser Doppler Velocimeter is also a candidate advanced ground-based detection system (see III.2, below).

III. Advanced Ground-Based Detection Devices

Several advanced ground-based sensors for remote atmosphere probing have shown promise for the MSDP Wind Shear System. All are in an early stage of development and no complete systems have been formulated about such devices.

1. Pulsed Doppler Microwave Radar

This type of radar is installed on the airport surface and scanned just above the horizon. Precipitation or variations in the index of refraction produce returns from along the line of sight, from which a radial profile of the atmosphere is extracted. Shears along the radials are detected and shear events are tracked, but downdrafts are not directly measured. The system has a more than adequate range and update rate. The antenna, however, is rather large (10-15 feet diameter) and the beam about 1° in vertical width, which limits the resolution with which horizontal shear can be distinguished from vertical.

2. CW Laser Radar (Laser Doppler Velocimeter)

A laser beam is directed along a vertical cone from the airport surface and backscatter from particulate matter provides the three components of wind velocity to fixed detectors. The wind components measured are those in the 50 to 1000-foot altitude range. Wind shear and winds aloft are made available. This is a compact equipment that gives information about the general wind motions above the airport, rather than along the departure and approach paths.

3. Pulsed Doppler Laser Radar

This device operates similarly to the pulsed Doppler Microwave Radar with the following differences. The laser is a more compact unit, not requiring a large antenna or drive; it has a much narrower beam, allowing observation closer to the horizon. The range, however, may be limited in heavy rain, fog, or snow.

4. CW/FM Microwave Radar

This microwave approach is similar to the CW Laser Radar described above, giving synoptic shear information in the 50 - 3300 foot range vertically above the airport surface. The antenna, however, is rather bulky compared to the laser device.

IV. Airborne Wind Shear Systems

The Airborne Wind Shear Systems being developed do not interact directly with the ATC System. Some minor modifications to ground based equipment may be required and are discussed below.

1. Groundspeed/Airspeed Comparison

The basic concept which has proven successful in manned simulation experiments for a wide range of shear conditions on approach is the groundspeed/airspeed comparison. Basically, it is a simple procedure whereby the pilot computes a minimum desired groundspeed based on the approach true airspeed and the ground winds in the landing area. He then flys a normal approach using indicated airspeed, except that he does not allow the groundspeed to fall below the predetermined value. The procedure automatically causes the pilot to add additional airspeed to compensate for any airspeed loss that will occur when the shear condition is reached. It is a predictive procedure so that if the amount of correction needed exceeds the known performance capability of the aircraft, the pilot is given the indication to perform a missed approach prior to penetrating the shear condition.

2. Wind Difference

This is basically the same procedure as the groundspeed/airspeed comparison except that the information is presented in a slightly different manner. Groundspeed is used to compute the wind component at the aircraft position and is compared with the wind in the landing area. The wind difference (the difference between the longitudinal components of the inflight wind and the ground wind) is presented to the pilot and represents the amount of shear which the aircraft is approaching and therefore the amount of airspeed that must be added before the shear is penetrated.

3. Modified Control Laws/Algorithms for Flight Director/Thrust Commands

In addition to the above systems, modifications are being developed for the control laws and algorithms which drive the flight director and thrust commands for control of the aircraft during approach. Modern systems are highly damped for passenger comfort and are not responsive enough for highly dynamic shear conditions. By providing the pilot with a selectable second set of control laws/algorithms which are quicker and more active, the ability to traverse wind shear conditions is greatly increased.

4. Groundspeed Information

The successful implementation of the above procedures is dependent upon providing accurate and timely groundspeed information in the cockpit. Several methods for providing this information are being developed. The options are:

a. Inertial Navigation Systems (INS). For those aircraft so equipped, groundspeed is readily available.

b. Instrument Landing System (ILS). A groundspeed sensor which utilizes the RF carrier of the localizer.

c. ILS. A groundspeed sensor which utilizes an audio subcarrier of the localizer RF.

d. Distance Measuring Equipment (DME). Equipment/modifications designed to optimize the range rate output.

e. Weather Radar. A groundspeed sensor which tracks a specially designed radar reflector on the ground.

f. Radar Altimeter. A system which correlates the transmitted radar altimeter signal received by two along-track antennas.

ARTS III ground speed is not presently (October 1977) being considered for use in airborne windshear systems. The ground-speed systems based on INS and Radar Altimeter would be self contained within the aircraft and independent of any ATC system. The others would require that the proper equipment be installed on the ground.

Three aspects of the air and ground system should be noted:

1. The system indicates only the <u>average</u> shear to be encountered from present aircraft position to touchdown. This indication may be zero even though very large increases and decreases in headwind, averaging to zero will be encountered to touchdown. These large changes in airspeed will be indicated to the pilot as they occur. It is important to ascertain the conditions under which pilot response will be adequate for corrective action.
2. The system indicates only horizontal shear, and gives no information on down-burst cells. It should be noted, however, that an aircraft cannot normally fly through a down-burst cell on approach without first encountering the strong horizontal wind changes associated with the cold air outflow.
3. The Air/Ground System is of little value in anticipating take-off wind shear, such as was responsible for the Denver Stapleton accident.

Air and Ground data derived from ARTS are not available within 1-2 miles of the antenna, which leaves the critical last minute before touchdown outside the system.

10.4.3 Interfaces with Controllers and Pilots

Information resulting from developments in wind shear programs may require (1) analysis, decisions,and actions by tower personnel and (2) the relaying of informaton to other personnel (e.g., pilots, NWS). The complexity of information displayed in the tower for the first requirement will depend upon the degree of sophistication of the algorithms developed for processing wind data, which in turn will depend upon successful developments in sensing, analyzing, and characterizing wind shear hazards. All of the information to be relayed will have to be displayed.

At the simplest level, average wind conditions are sensed with anemometers for each runway and displayed in the tower, for interpretation by the controller. Aside from adding undesirable tasks to the controller's workload, this procedure requires wind displays, with the tradeoffs discussed under wake vortex displays. This is an interim approach and will likely not be in widespread use during the MSDP time period.

Multisensor arrays lead to the next level of display sophistication. Although more data are collected than with runway anemometer systems (e.g., temperature, pressure, pressure jump), more automated data analysis is also provided. The parameters to be displayed to the controller have not been determined, because they will depend on the results of ongoing research on wind shear prediction and the dynamic effects of wind shear prediction and the dynamic effects of wind shear on aircraft. It is safe to guess, however, that a simple hazard index will be derived and that concise information on hazard location and movement will be made available for display. Very likely audible and visual alarms will also be actuated in the tower for severe conditions. The potential will very likely exist for symbolic representation of shear lines on the ARTS and TAGS PPI displays, possibly with the alphanumeric data blocks to indicate hazard level and parameter values. If the reliable algorithms can be developed to determine runway selections and closings automatically, even simpler display requirements may be possible.

Some wind shear programs may result in more detailed forecasts and warnings of impending wind shear conditions. Some of this information will very likely be relayed to the pilots through the tower, along with summaries of pilot reports and locally sensed data. Some of this information may have to be screened and recorded on ATIS (or its equivalent) at the Flight Data position. At LAWRS (Limited Aviation Weather Reporting Service) towers, wind shear information will have to be monitored and included in regular and special observations and disseminated to the weather net. Generally, present or contemporary devices for receiving and relaying weather data will be used, the wind shear data simply comprising additional terms in regular messages. LAWRS towers, however, may need more readouts from local sensors than will the towers outfitted with NWS observing stations.

Two potential MSDP developments may eventually ease the tower workload considerably with respect to wind shear data handling. Should the tasks in the wind shear program aimed at developing airborne sensors of wind shear prove successful, there may be less need for tower personnel to relay ground-sensed data to aircraft. Also, the DABS data link may permit automatic generation and transmission of wind shear advisories and related commands.

The wind shear research under the MSDP's will interact with broader developments to affect the jobs of tower personnel. In particular, the National Transportation Safety Board (NTSB) has made recommendations, which, if acted on, will require that both tower personnel and pilots be given special training on the recognition of, evaluation of, and reaction to wind shear hazards. Aside from making the tower personnel more "wind shear conscious," this training together with new procedures, result in special data needs of tower personnel and may affect requirements for data displays. Pilots will very likely initiate more requests for wind shear advisories as a result of this training, thus adding to the data relaying workload in the tower.

10.4.4 Failure Modes

At the present time, no failure modes have been provided because of the preliminary nature of all these systems. Because of the relatively low frequency of wind shear conditions, system reliability requirements probably will not be high. If the failure detection method is itself fail-safe (i.e., gives a GO indication only if the failure detection system as well as the equipment is functional) then present wind shear procedures can provide the back-up mode. In such cases, the system would be no less safe than current practice.

10.4.5 System Status and Development Plans

The Wind Shear program is broken down into seven major sub-programs:

1. Wind Shear Characterization
2. Hazard Definition
3. Ground-Based Systems
4. Airborne Systems
5. Wind Shear Data Management
6. Wind Shear Prediction
7. Systems Integration and Implementation.

Projects 3, 4 and 7 are of particular interest to this study; their status will be discussed here.

The milestone chart for the Ground-based Systems sub-program, taken from the Wind Shear Engineering and Development Plan,[4] is given in Figure 10.4-6. It shows the major projects or tasks for each type of sensor through Test and Evaluation. The results of tests on all of the systems should be available by the end of 1977.

The milestone chart for the Airborne Systems subprogram is given as Figure 10.4-7. The three tasks, manned flight simulation, groundspeed sensor development and flight evaluation, are scheduled

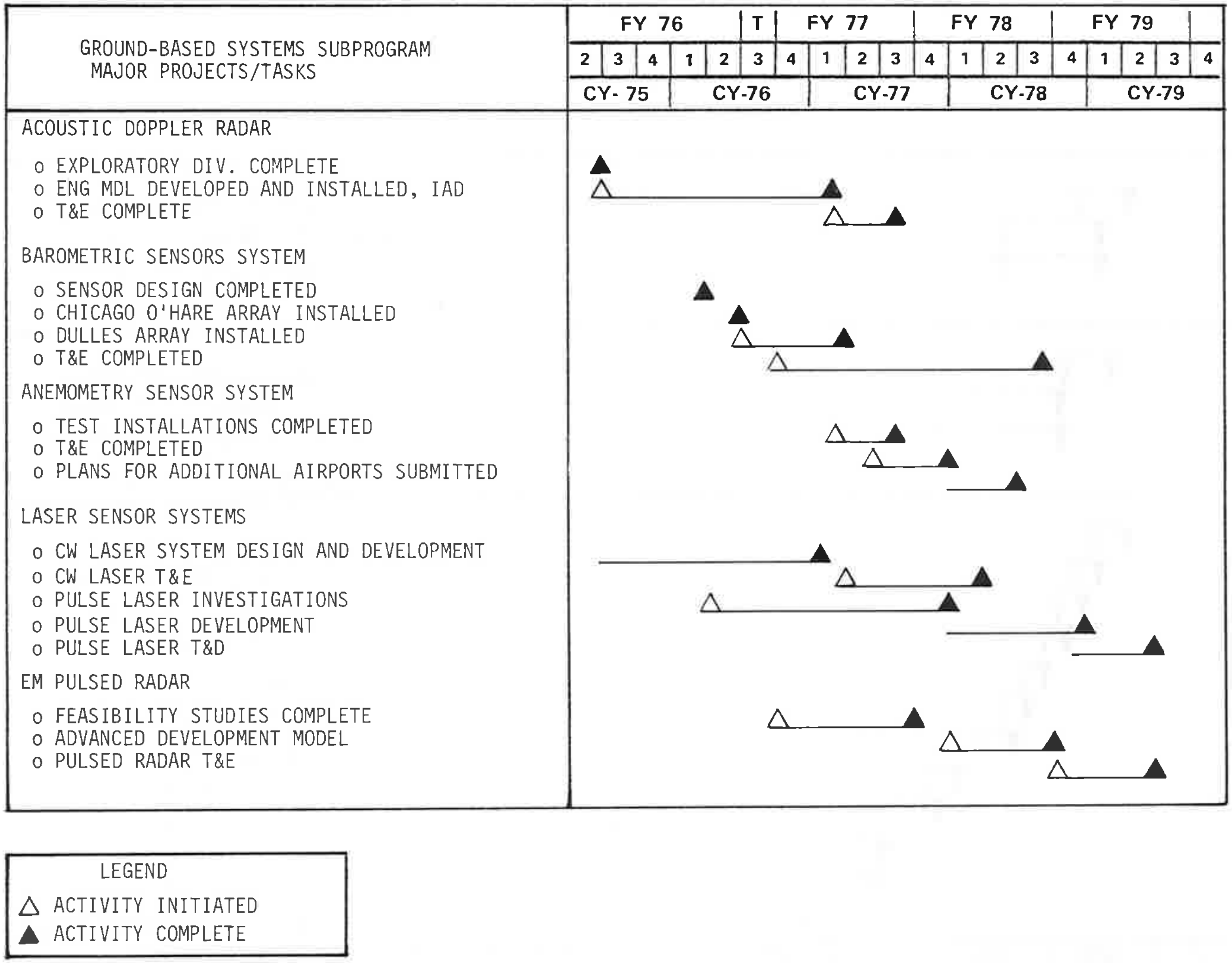

FIGURE 10.4-6. GROUND-BASED SYSTEMS MILESTONES

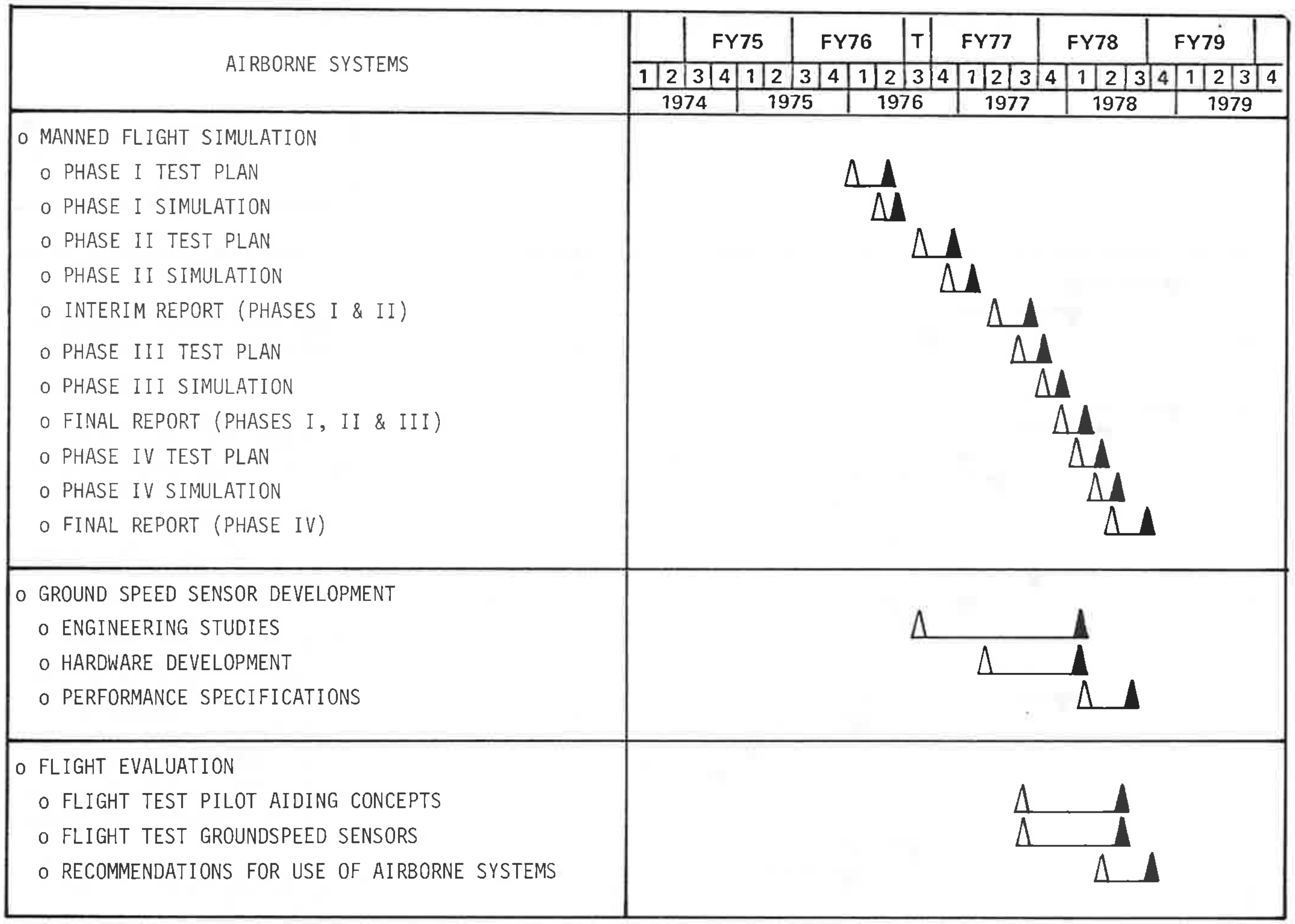

FIGURE 10.4-7. AIRBORNE SYSTEMS MILESTONES

for completion by the end of 1978, culminating in recommendations for the use of airborne wind shear detection systems.

Meantime, the Systems Integration and Implementation subprogram, whose milestones are shown in Figure 10.4-8, will be developing a plan "for the efficient and economical integration of the Wind Shear Systems into the National Airspace System (NAS)." This plan is to be ready at the end of 1979.

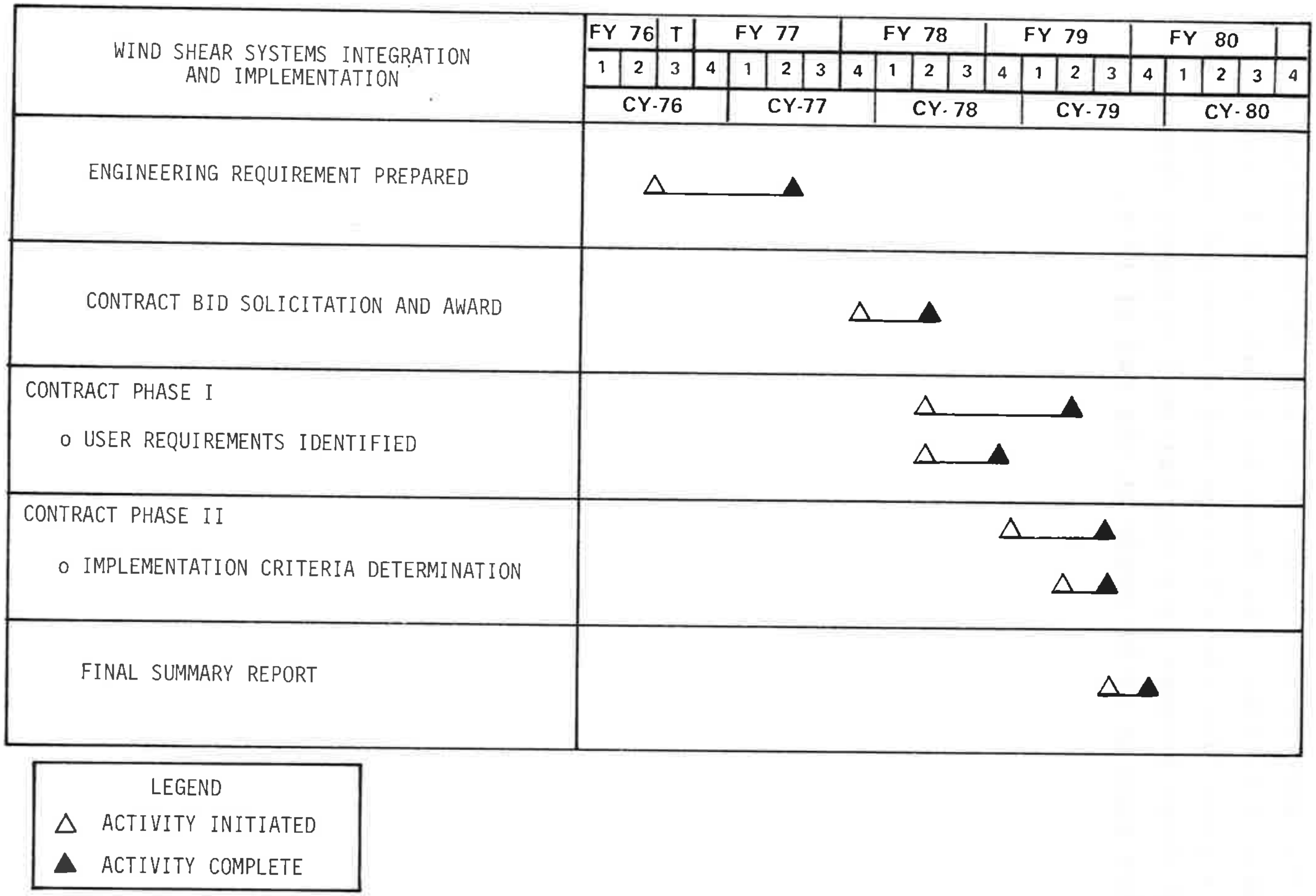

FIGURE 10.4-8. WIND SHEAR SYSTEMS INTEGRATION AND IMPLEMENTATION MILESTONES

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11. LANDING SYSTEMS

11.1 MICROWAVE LANDING SYSTEM

11.1.1 Introduction

The current Instrument Landing System (ILS) was demonstrated in 1929, adopted for national service in 1941, and as an international standard by the International Civil Aviation Organization (ICAO) in 1949. Only about ten percent of the airports throughout the country which have paved and lighted runways are ILS equipped, however, these airports account for over 80 percent of all instrument approaches. Over 90 percent of all airline activity and nearly 100 percent of all jet airline traffic use airports equipped with ILS.

Through FY 76, 528 ILS facilities have been installed. Planned installations through FY 80 will raise this total to 640.[1] About half of the existing facilities are of the older vacuum tube design with inherently higher annual operation and maintenance costs and lower reliability than the more recent facilities which are of solid state design with improved reliability and reduced annual costs.

Although the ILS is still providing satisfactory precision landing guidance, the need for a new precision approach and landing system was documented in the Department of Transportation Air Traffic Control Advisory Committee (ATCAC) report of December 1969[2] and by the Radio Technical Commission for Aeronautics (RTCA) in its Special Committee (SC-117) Report of December 1970.[3] The ATCAC report indicated that the projected demand for precision landing guidance would exceed the capabilities of the present system and concluded that a Microwave Landing System (MLS) was required as part of the future National Aviation System. Approved by FAA and DOT, the ATCAC report influenced the work of RTCA SC-117 which subsequently produced a comprehensive recommendation for a new guidance system for approach and landing intended to meet both civil and military requirements through at least the year 2000. This program is described in the National Plan for Development of MLS dated July 1971 which was jointly prepared by FAA, DOT, DOD, and NASA, all of whom are program participants.[4] The MLS program of the U.S. is designed to mesh with the international effort of ICAO toward the goal of developing an international standard MLS system.

MLS PROGRAM OBJECTIVES*

The MLS program was established with the following objectives:

a. Develop a new precision landing guidance system by 1977 which will have (1) increased performance relative to the present UHF/VHF Instrument Landing System (ILS), (2) less costly and stringent requirements for site preparation and installation, and (3) a sufficient number of channels to accommodate the increased total number of installations anticipated (1,000 to 1,500 ground systems).

b. Develop a basic system which can provide increased performance through modular additions, so that the capability and costs can be tailored to satisfy differing requirements of various airports and users.

c. Provide for curved or segmented approaches, so that approach paths can be selected for minimum noise impact on the community, consistent with aircraft flight characteristics. This improvement in flexibility of the service directly supports the overall goal of improving performance.

d. Provide a single standard for "signals-in-space" which will satisfy the principal needs of the international and U.S. civil and military users. This would eliminate additional costs of several proliferating systems and add to the safety of emergency operations.

e. Complete the essential development of the MLS at an early date for evaluation by other International Civil Aviation Organization (ICAO) members.[11]

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*This section taken principally from ref. 5, pp. 2-1 to 2-6.

GENERAL CHARACTERISTICS OF THE MLS

The MLS discussed below was derived from the recommendations of RTCA SC-117 and of the Department of Transportation's Air Traffic Control Advisory Committee for a new precision approach and landing system to meet all civil and military needs throughout at least the balance of this century. The program is a joint effort of the Departments of Defense and Transportation and the National Aeronautics and Space Administration, with the FAA responsible for the management and direction of the overall effort. The program is being conducted and accordance with the 'National Plan for Development of the Microwave Landing System.'[4]

The MLS is an air-derived system; that is, ground stations will generate and transmit coded signals which will enable each airborne receiver/processor unit to derive its precise azimuth and elevation angles as well as range data. These data will be suitable for display to the pilot or for use by an automatic flight control system. In addition, auxiliary data, including runway identification, the condition of the runway, the operational status of the guidance system, and weather data, may be provided to aircraft via a ground-to-air data link.

The MLS design is modularized so that different levels of avionics performance capability and cost, to satisfy the differing requirements of various user categories, can be attained through different configurations. Thus, all airborne and ground-based components of the system will be compatible with each other and, in any particular operational situation, the service provided by any combination of a ground facility and an airborne unit will be limited only by the capability of the less sophisticated of the two.

A ground-system modularity concept is also being followed which is consistent with the concept presented in the SC-117 report and the MLS National Plan. More specifically, a "basic system" for most civilian needs will be developed to include a series of modules which can be procured to provide differing levels of capability depending on the economic constraints and performance requirements at the airport under consideration. Under this concept, any functional element of the MLS such as the azimuth or elevation angle unit, could be built to include one of several levels of capability in accuracy or coverage. In some cases, however, it may be desirable to have specific designs to meet unique needs.

RTCA identified two techniques for providing azimuth and elevation angle information; scanning beam and Doppler scan. In the scanning beam technique, narrow, encoded beams (one for azimuth and one for elevation) are swept across the field of coverage. The aircraft can determine the scan angle by use of on-board electronics. The Doppler scan produces a simultaneous set of beams in space, one set for azimuth and the other for elevation. Each beam is at a slightly different frequency, so that the aircraft can determine angle information by use of on-board electronics. One of the MLS program activities has been to conduct tests and analyses to help determine which technique should further be developed. This led to the selection by the U.S. in February 1975 of a scanning beam (with time-reference-encoding) method.

MLS ground units with wide-angle-coverage and curved-segmented approach capability will be provided for the Category I, II, and III versions.* Also, a lower-cost, Small-Community MLS (SCMLS), with only narrow-angle-coverage and straight-in approach capability, will be provided for use at the smaller Air Carrier airports and General Aviation airports where curved/segmented approaches are not required. The SCMLS will provide acceptable service during Category I weather limits.

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*CATEGORIES OF OPERATION FOR PRECISION APPROACHES

Category	Decision Height	Runway Visual Range
I	200 feet	2400 feet
II	100 feet	1200 feet
IIIa	0 feet	700 feet
IIIb	0 feet	150 feet
IIIc	0 feet	0 feet

A range of MLS receivers will be available so that users would have to buy only that equipment necessary to meet their requirements. The most expensive avionics equipment would provide the maximum capability for which the sophisticated ground sites are designed.

ADVANTAGES PROVIDED BY MLS

Potential Advantages of MLS over ILS are as follows:

Performance

- Increased ATC coverage will result from the ability to provide precision guidance (including Category II and Category III operations) at a substantially increased number of airports. MLS can be installed at certain sites whose difficult terrain precludes use of conventional ILS either because of physical obstructions to low-angle approaches or because of the deleterious effects of the terrain on ILS signal propagation.

MLS can be expected to provide significantly higher levels of system reliability because of greatly reduced interaction with the site. Occurrences such as rain, snow, and aircraft movements will have a negligible effect on the MLS guidance signals.

MLS will enable flight paths to be adapted to current operational considerations. For example, at J. F. Kennedy airport in New York, there is an approach over a bay to reduce noise (the "Canarsie" approach); MLS would permit this short, curved approach to be conducted under IFR weather conditions.

MLS will enable use of a range of vertical glide slopes, both to reduce noise and to accommodate different classes of aircraft. For example, STOL aircraft may normally approach the landing site at much steeper glide slopes than the normal 3-degree angle. MLS could give continuous electronic guidance throughout such approach paths.

Safety

A major benefit of MLS relative to ILS is expected to be the enhanced safety that is achieved as a result of the installation of precision approach and landing aids at more airports. The ability to install MLS at more airports and at more runway ends results from both (1) availability of sufficient frequency channels, and (2) in some cases, greatly decreased interaction between the site and the MLS, and, therefore, lower costs of MLS site preparation.

Costs

Costs for new ground-based MLS facilities , particularly Category II and III facilities, are expexted to be less than ILS costs, due to reduced site preparation costs. However, MLS avionics may initially cost more than ILS avionics.

A common standard system for both military and civil use would eliminate a proliferation of special purpose military systems. Commonality should ultimately result in lowering R&D, implementation, and avionics costs. This advantage accrues to the national benefit, not just to civil aviation.

11.1.2 System Description

The Microwave Landing System (MLS) is a precision approach and landing guidance system designed to satisfy all present civil aviation requirements and those that can be foreseen for the next 30 years. In addition, this system is satisfactory for most military non-combat requirements. MLS provides more diversified service and higher accuracy, with greatly reduced site constraints, than the present Instrument Landing System (ILS). Moreover, the MLS and ILS can function simultaneously in the same airport environment without one interfering with the other, which will aid considerably in the transition from the ILS to MLS.

The system selected by the U.S. as the national standard and recommended to ICAO for the international standard is based on the Time Reference Scanning Beam (TRSB) technique. Another technique using the Doppler principle has been proposed to the International Civil Aviation Organization (ICAO) by Great Britain. At this system has been recommended by a majority of the members of the ICAO-All Weather Operations Panel (AWOP). The interfaces with the tower cab and the workload on the ATC controller will be very nearly the same for either the TRSB or Doppler system. Therefore the discussion in this section will address only the TRSB system.

MLS is an "air-derived" system in which the aircraft determines its own position directly and independently of other on-board or ground elements of the ATC system. This system embodies three major categories of measurements used in deriving the three dimensional guidance information as follows:

a. Angle guidance measurement in azimuth and elevation using the TRSB technique at C-Band (or Ku-Band for special applications).

b. Flare guidance by the standard radar altimeter, or, alternatively, by the TRSB technique.

c. Range measurement using a precision L-Band Distance Measuring Equipment (DME), designed to be compatible with existing systems.

An aircraft determines its position by making the following three measurements: 1) approach azimuth angle referenced to the runway centerline, 2) an elevation angle measurement referenced to the horizontal, and 3) a range measurement referenced to the azimuth/DME site. The TRSB MLS is used to make the azimuth and elevation angle measurements.

The TRSB technique consists of two basic elements: the ground subsystem which scans the coverage volume in azimuth and elevation while transmitting coded signals to the aircraft and the airborne subsystem which included a receiver/processor with outputs to standard displays in the aircraft.

11.1.2.1 System Concept and Functional Characteristics

11.1.2.1.1 Angle Guidance. The TRSB signal format is based on the TO-FRO scanning beam technique, in which narrow fan beams scan through the coverage volume in alternate directions. The beams are scanned at high speed and consist of a single, unmodulated, continuous radio frequency transmission. The scanning speed is uniform, starting from one extremity of the coverage sector and moving to the other and then back again to the starting point, thus producing a TO-FRO scan. The azimuth beam scans first counterclockwise and then clockwise, as viewed from above. The elevation beam scans first down and then up. In every scanning cycle, two pulses are received by the aircraft. The time interval between the TO and FRO pulses is proportional to the angular position of the aircraft with respect to the runway. An important feature of the time reference encoded scanning beam system is the high data update rate, 13.5 Hz for azimuth and 40.5 Hz for elevation. These data rates make it possible to design simple airborne processors that can minimize any multipath effects on guidance signal quality.

All angle data functions are time-multiplexed on the assigned radio frequency so that a single receiver-processor channel may process all data. Since each function is an independent entity in the function sequence, the receiver may decode functions in any sequence. This is* accomplished by providing each function with a preamble that, upon reception, sets the receiver for the function which follows. The function identification preamble is radiated on a sector antenna covering the function guidance volume. The scanning fan beam and the sector transmission are illustrated in Figure 11.1-1.

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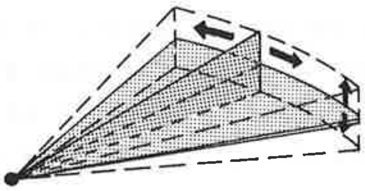
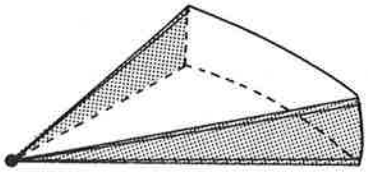
*Ref. 6, pp. 1-1.4.



(a) Scanning Beam
Angle Data



(b) Identification and
Other Data Signals

FIGURE 11.1-1. REPRESENTATION OF THE ANGLE AND
PREAMBLE RADIATION CHARACTERISTICS

All angular information is essentially linear throughout the volume coverage. Precision azimuth angle guidance is provided to at least ±40°, or a narrower sector if desired. For any installation, and particularly where proportional coverage is reduced for reasons of economy, left-right guidance information may be provided over a wider sector. Precision elevation angle guidance, referenced to a standard reference point, is provided from 1° to 20° in elevation, over the same sector that provides azimuth angle guidance. Precision missed-approach azimuth angle guidance, referenced to runway centerline, is provided to at least ±20°.

The standard signal format contains a time slot for the addition of 360° azimuth and missed-approach elevation guidance to meet potential future requirements, and the design concept is sufficiently flexible to permit the use of either electronic or mechanical antennas for a 360° azimuth capability. Such an alternative could be implemented at C-Band or Ku-Band.

11.1.2.1.2 Range Determination. Range information is obtained in suitably equipped aircraft in the conventional manner by measuring the round trip time between the transmission of interrogation pulses from aircraft and reception of corresponding reply pulses from a ground transponder. The ground transponder is typically located near the stop end of the runway co-located with the approach azimuth system. An L-Band Distance Measuring Equipment (DME) that is compatible with existing equipment and provides improved accuracy and channelization capabilities is the choice for implementation. Since the same equipment is used for approach and landing as well as en route navigation, the airborne user can utilize the operational capabilities of MLS at significant cost savings. Lower levels of service may be obtained without DME by the use of beacons* to indicate progress on approach. The U.S. has also developed C-Band DME. While it is the U.S. view

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*Ref. 6 , pp. 1-1.5.

that every effort should be made utilize L-Band DME for the MLS ranging function, C-Band DME remains as an element of the MLS signal format in the event that L-Band DME cannot be implemented, particularly for some military requirements. Should it be decided later that there is no need for C-Band DME, appropriate deletions from the signal format can be made.

11.1.2.1.3 Flare Guidance. The TRSB format includes a flare element. Flare elevation equipment was tested in the U.S. MLS development program to demonstrate the feasibility of providing such a signal. The flare elevation element should be a part of the signal format to accommodate special and unusual circumstances and to provide for potential applications in the future; however, for a number of practical reasons, it is expected that automatic landings can and will continue to be accomplished using approach elevation signals and radio altimeters and without the need for a separate flare elevation signal. Therefore, most MLS systems may be implemented without a flare elevation element.

11.1.2.1.4 Data. TRSB has an extensive data capability. Data is transmitted to all aircraft within the coverage sector using Differential Phase Shift Keying (DPSK) modulation. Essential data is included in function preambles. It is decoded by all user aircraft. Auxiliary data* are time-multiplexed with the angle functions and contain information for more complex services such as missed-approach and curved paths. This information includes the status of ground equipment and siting geometry. Growth potential is available also in the data format.

11.1.2.1.5 Signal Format. TRSB uses a signal format that assures inter-operability among a broad range of ground facilities and airborne equipment. The various functions are time-multiplexed and sequentially radiated on the same frequency. The receiver identifies each function by its preamble and then decodes the

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*Ref. 6, pp. 1-1.5 and 1.6.

angle information. The technique is flexible in that any combination of functions may be radiated by ground stations and arranged in any order without affecting proper operation of any receiver, and alternate formats may be employed to meet special national requirements. The minimum update (data) rates for the angle functions are shown in Table 11.1-1*.

TABLE 11.1-1. ANGLE FUNCTION UPDATE RATES

Function	Updates per second (minimum)
Azimuth	13.5
Elevation	40.5
Flare	40.5
Missed-approach azimuth	6.75
360° azimuth	6.75
Back elevation	6.75

Growth potential is inherent in TRSB because;

(1) Projected future requirements for 360° azimuth back elevation are incorporated in the format.

(2) Future function requirements may be accommodated by defining new function formats using spare function identification words. Such new functions are easily incorporated in the time-multiplexed TRSB signal format.

(3) Future requirements for additional auxiliarly data words are easily incorporated in the time-multiplexed TRSB signal format. (Note: These words may be used to give the pilot the status of other systems, such as the DABS).

11.1.2.2 System Configuration

11.1.2.2.1 Ground System. The signal format allows a large variety of compatible equipments to be installed in a given

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*Ref. 6, pp. 1-1.6, 1.9 and 1.11.

facility. The U.S. currently has identified three major configurations to satisfy the range of requirements. These are: (a) basic, (b) expanded, and (c) small community. See Figure 11.1-2.

a. The basic configuration consists of the following subsystems:

(1) Approach azimuth, nominally located on the runway centerline beyond the stop end

(2) Approach elevation, nominally located beside the runway near touchdown

(3) DME transponder, nominally located beside the azimuth equipment

Two variations are provided for by the format:

(a) Dual azimuth subsystems, located beside the runway to "see over" runway humps.

(b) Co-located facilities, where all equipment is located at the elevation site.

b. The expanded configuration consists of all the basic subsystems plus the missed-approach and flare subsystems. The expanded configuration is designed with full redundancy to meet all the operational requirements of ICAO and all Category III requirements.

When coupled to suitable flight control systems, the expanded configuration will allow the following types of approaches within a coverage volume of up to ±60° in azimuth and up to 20° elevation.

(1) Curved-approach tracks
(2) Segmented-approach tracks
(3) Straight-approach tracks

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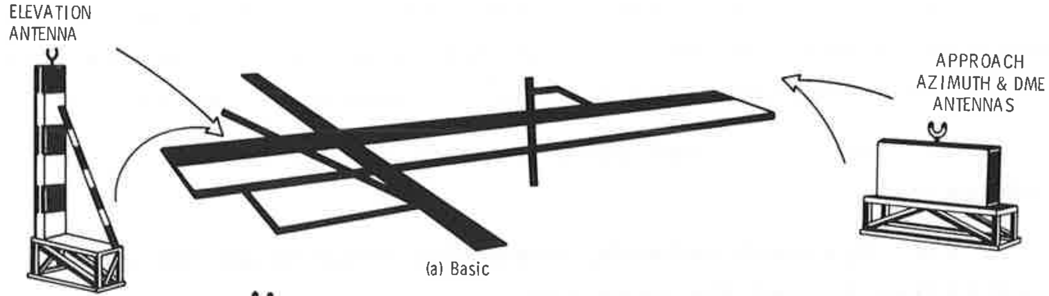
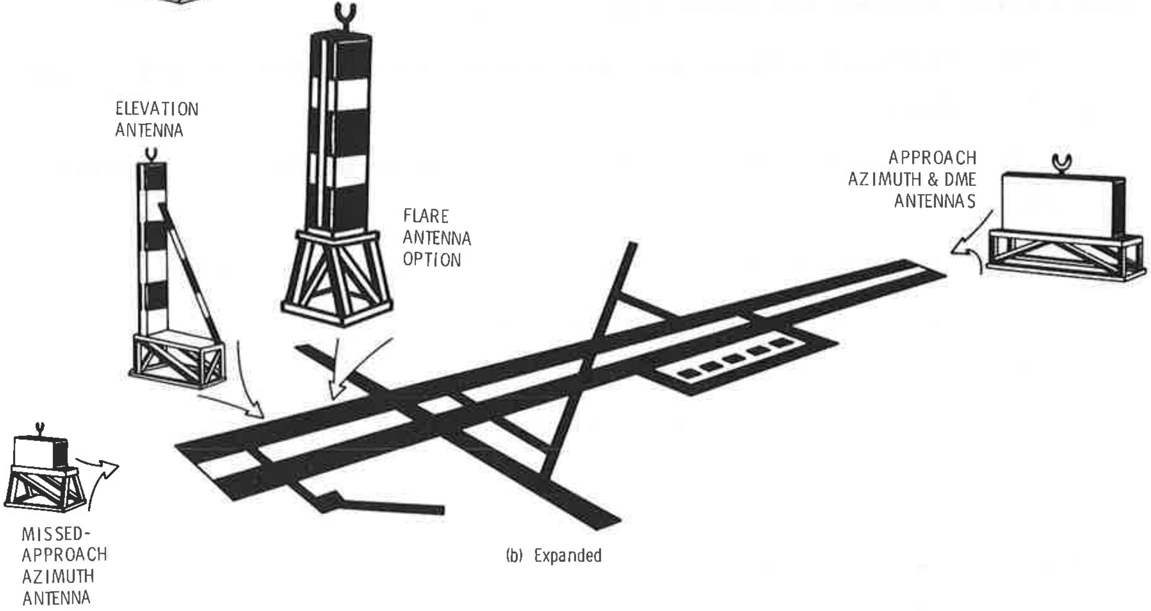
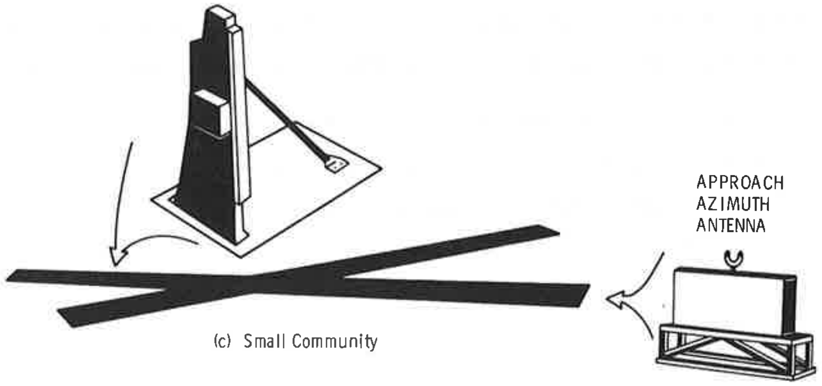
*Ref. 6, pp. 1-1.9, 1.11, and 1.13.



(a) Basic



(b) Expanded



(c) Small Community

FIGURE 11.1-2. EXAMPLES OF TYPICAL GROUND CONFIGURATIONS

(4) Pre-selected descent profiles
(5) Curved-descent paths
(6) Segmented-descent paths

c. The small community configuration meets ICAO requirements for a minimum service system and consists of:

(1) Approach azimuth

(2) Approach elevation

(3) DME or ICAO standard marker beacons

The equipment has less redundancy and may have less coverage and accuracy than that of the basic system, thereby supplying an economical means of providing Category I service at small airports.

Auxiliary data, left-right guidance, and sidelobe suppression signals may be provided with any of the configurations. They are transmitted through fixed sector antennas.

A ground subsystem is defined as a set of compatible functional elements that are configured to provide a desired operational capability. Regardless of level of capability, interoperability of all airborne and all ground configurations is a fundamental feature of the U.S. system. A typical TRSB facility is shown in Figure 11.1-3, and block diagram is given in Figure 11.1-4.

11.1.2.2.2 Airborne Subsystem. Airborne designs stress the modular concept so that all users may independently procure only what they consider essential while still obtaining service from all ground facilities. To obtain approach and landing guidance at the lowest cost at any TRSB equipped airport, an aircraft need have only an antenna and a receiver-processor unit operating with existing ILS displays. At the other extreme, an aircraft equipped for Category III will carry redundant MLS equipment and interface with the Automatic Flight Control System (AFCS).

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*Ref. 6, pp. 1-1.13.

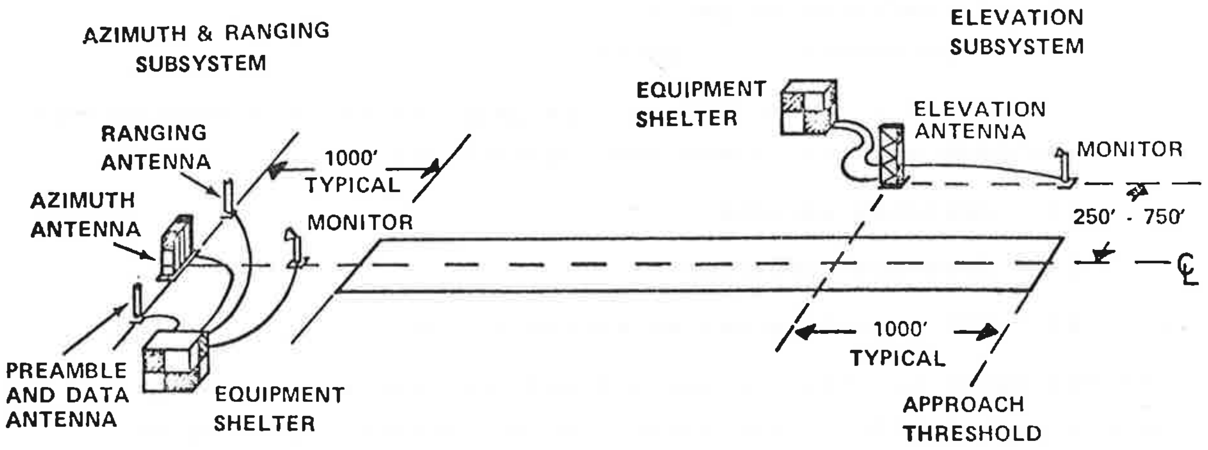

FIGURE 11.1-3. TYPICAL TRSB FACILITY

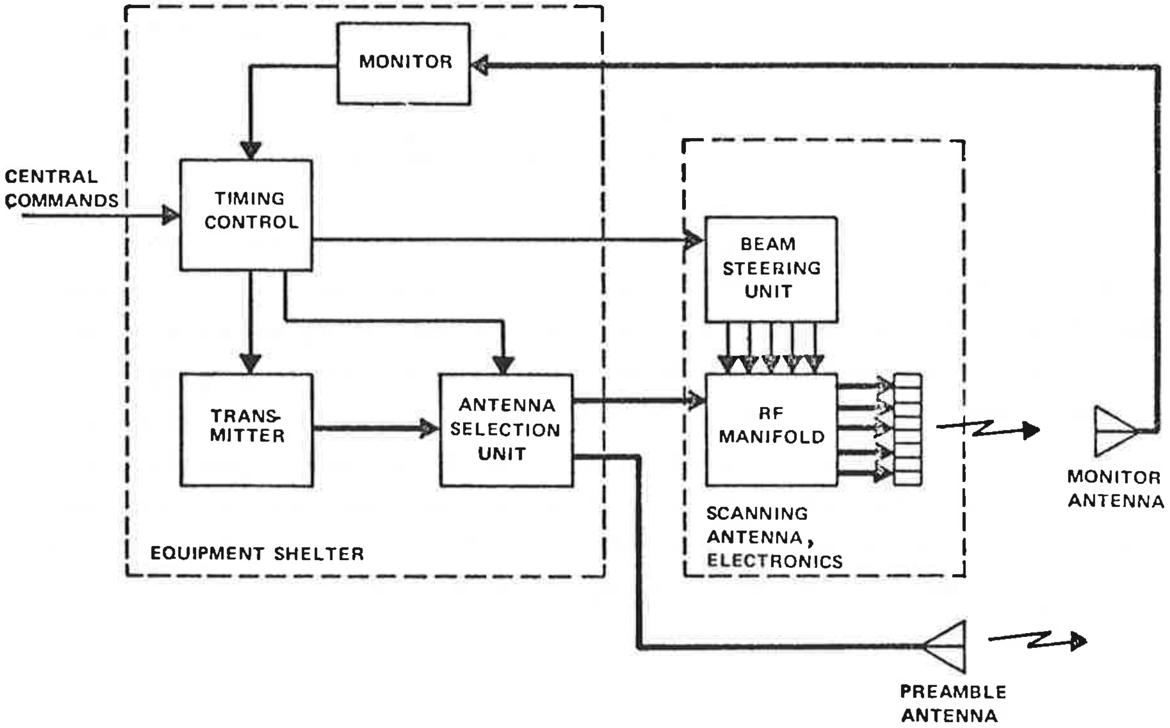

FIGURE 11.1-4. TRSB GROUND SUBSYSTEM BLOCK DIAGRAM

The low-cost airborne receiver, intended for general aviation aircraft, generally will be limited to a single glidepath and to centerline approaches. Progress on the approach can be provided by standard marker beacons if DME is not used.

All of the various ground-airborne configuration combinations are designed for interoperability. A simple general-aviation airborne unit obtains service from the most complex ground installation, at a level of capability associated with the airborne subsystem.

Likewise, the air-carrier type airborne unit obtains service from the small community ground installation, at a level of capability associated with the ground subsystem. TRSB spans the entire range of approach and landing operations for all known aircraft types. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users ranging from general aviation to major air carriers are accommodated. Also, TRSB is adaptable to special situations, such as transportable or shipboard configurations.*

11.1.2.3 Implementation Considerations - The TRSB MLS can be installed and satisfactorily operated at almost any airport, principally because of its basic design characteristics. Siting is comparatively simple, modular configurations are available and subsystem siting is flexible. Site preparation required to provide a suitable signal will be minimal for MLS, since microwave frequencies allow for the use of narrow beams and controlled antenna patterns, thus reducing radiation toward the ground.

TRSB is designed to operate in the presence of multipath signals generated by local terrain, airport buildings, and traffic movements either on the approach or on the ground.

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*Ref. 6, pp. 1-2.193 to 2.214 and 2-1.1 to 2-5.2.

The sidelobe suppression provision in the signal format eliminates possibilities of false courses caused by reflections from all but the most adverse combination of strong reflections and direct signal path shadowing. To cope with adverse cases, MLS has the capability of avoiding illumination of the troublesome object by a adjustment of the scan coverage limit.

TRSB assists in achieving maximum airport landing rates by providing accurate approach and landing guidance for curved or segmented approach paths with minimum separation. All angle measurement functions have unlimited traffic handling capacity. The DME can serve more than 100 aircraft simultaneously.

Since the TRSB will provide for an all-weather landing capability, meteorological restrictions such as cloud base or limited visibility will not restrict the operation of the full system.

In order to meet the full range of conditions which might be required for operations at all sites, different azimuth modules with beamwidths ranging from 1° to 3° have been identified. The system designer combines the selected azimuth module with selected modules for the other required functions to satisfy conditions at a particular airport. The modular concept can also be employed in specifying functional element coverage. For instance, in elevation, a high-capability airport might require a full range of glide paths from 2° to 15°. A small-community airport might use a range from 2.5° to 8°. With modular elevation elements, discrete levels of antenna coverage can be designed to the full range of needs.*

11.1.2.4 Coverage Volume

11.1.2.4.1 Azimuth - The approach azimuth guidance element provides proportional lateral guidance coverage to ±40° from

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*Ref. 6, pp. 1-3.233 to 3.304 and 2-1.1.

runway centerline (the signal format allows up to ±60° coverage) from 1° in elevation (or the obstacle clearance surface in the approach zone) to 20°, to a range of 20 nautical miles*.

Longer range is achievable (e.g., 30 nautical miles) by appropriate increases in power and sensitivity. Elevation coverage of the azimuth guidance element is up to 20,000 feet bounded by the 20° elevation angle limit.

Proportional deviation is provided from any selected angular path within the sector.

The approach azimuth guidance element provides proportional lateral guidance coverage over the runway between the threshold and the stop end of the runway for landing and rollout guidance.

Depending on antenna location and runway surface contour, azimuth information is provided from near the surface (∿ 3ft)to at least 150 feet above the runway centerline.

The azimuth position information is linear within the coverage volume.

The missed-approach azimuth guidance element provides proportional guidance coverage to ±40° from the runway centerline, from 1° in elevation (or the obstacle clearance surface in the departure zone) to 20°, to a range of 7.5 nautical miles from the threshold. Longer range is achievable by increasing transmitter power.

Missed-approach azimuth guidance is provided to at least 2,000 feet above the runway stop end, assuming this is at least 5,500 feet from the missed-approach azimuth antenna. Additional left-right guidance can be provided beyond the ±40° sector of proportional guidance if desired.

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*Ref. 6 , pp. 2-4 to 2-12.4.

The missed-approach guidance will be adequate to safely conduct simultaneous operations on closely spaced parallel runways.

Transition from approach to missed-approach guidance will be smooth in the overlapping coverage regions above the runway surface due to the high accuracy of both azimuth guidance subsystems in this region.*

11.1.2.4.2 Vertical - The elevation guidance element provides proportional vertical guidance coverage to ±40° from runway centerline, from 1° in elevation (or the obstacle clearance surface in the approach zone) to 20°, and to a range of 20 nautical miles. Longer range is achievable (e.g., 30 nautical miles) by increasing power of sensitivity. The signal format allows coverage up to 30° in elevation.

Within the defined sector, the guidance information is an unambiguous linear function of angular position.

This linear function is common to all system configurations.

The TRSB flare guidance element provides proportional vertical guidance coverage in the final approach region, in a limited sector (±20°) along runway centerline and over the runway touchdown zone from near the runway surface to a height of at least 150 feet.

Flare angle guidance plus DME range guidance data may be used to compute a flare maneuver sufficiently accurate to perform precision automatic landing.

Vertical position information from any elevation or flare guidance element will permit aircraft to be guided accurately on constant elevation angle paths on selectable glideslopes between 2° and 15°. With configurations that provide distance information, any linear tracks, curved tracks, segmented tracks, or combinations

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*Ref. 6, pp. 2-12.1 to 13.1

thereof may be flown using position derived from elevation and range within the proportional coverage zone; flare paths to touchdown also may be flown using position derived from flare elevation and range. Aircraft guidance stability* on such paths is assured by the high data rates provided.

Vertical position information is available simultaneously to all aircraft within the entire system coverage volume.

11.1.2.5 Synchronization of Functions - The TRSB signal format employs Time Division Multiplexing (TDM). The TDM format requires synchronization among the various angle stations on a given runway so that only one function is radiated at a time. As shown in Figure 11.1-5, synchronization is provided by a central control unit, which sends out start commands to the angle and data subsystems. (The ranging subsystem is independent.) Status is sent from the various subsystems to the central control unit, which determines what action is to be taken, and what advisories to send up on the auxiliary data link. These advisories and status information are also provided to ATC. Several techniques such as the use of land lines or VHF radio links are available for relaying timing, control, status, and other data between the central control unit and the various subsystems.

11.1.2.6 System Integrity - The TRSB MLS is comprised of both ground and airborne equipment designed to provide precise guidance of high intergrity. Integrity features of the TRSB MLS validate correctness of operation and inform users of any change in status The airborne subsystem will contain automatic means of error checking and an ability to make simple, complete system tests by use of a radiated test signal. The ground subsystem will possess an automatic monitoring capability to detect out-of-tolerance conditions, to provide warning to designated control points, and

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*Ref. 6, pp. 2-13.1 and 13.2.

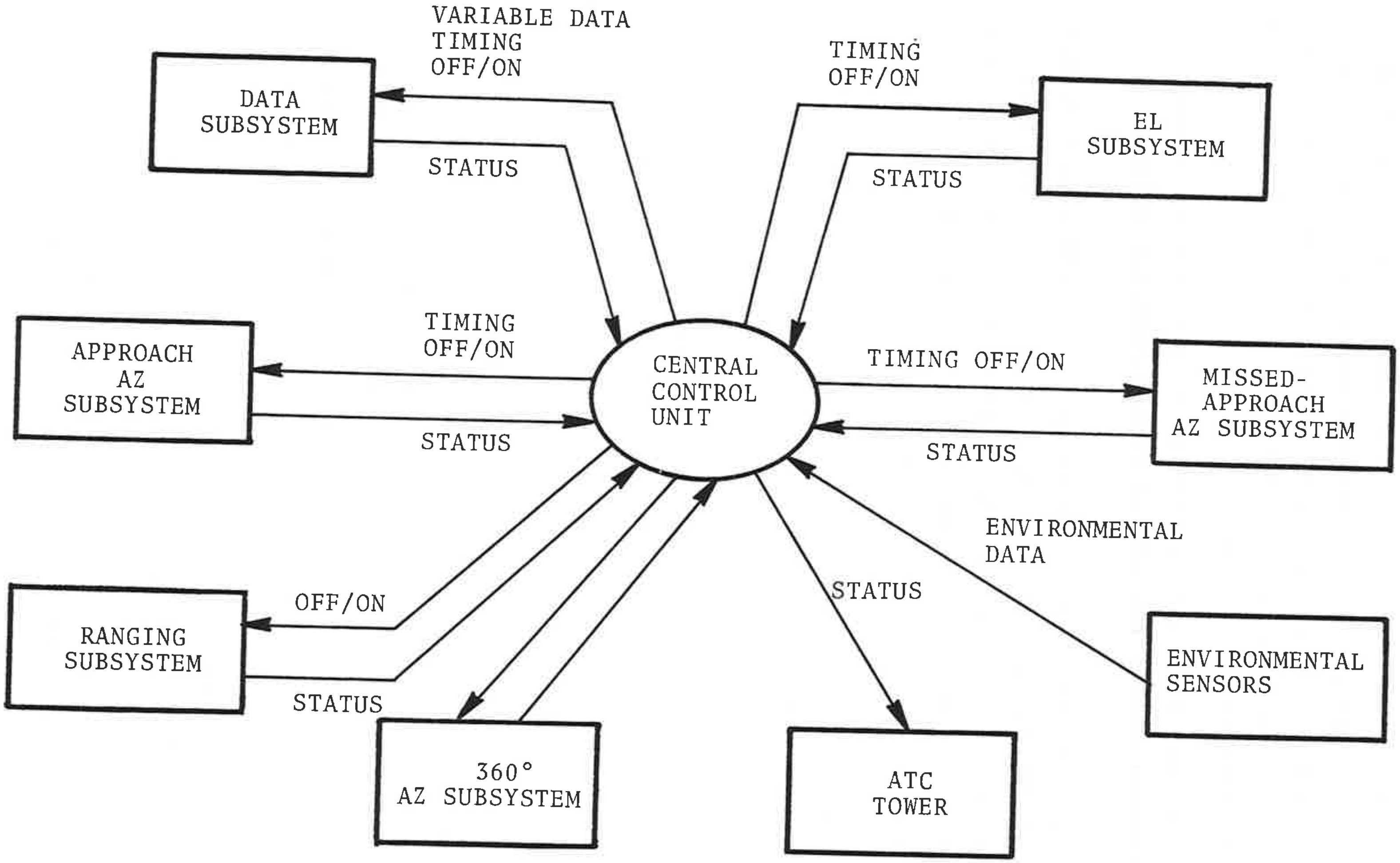

FIGURE 11.1-5. SYNCHRONIZATION AND INFORMATION FLOW OF AN MLS FACILITY*

*Ref. 1, pp. 1-2.81.

either to revert the subsystem to a lower category of operation or terminate radiation. Availability will be assured through the design features for reliability and maintainability. The TRSB-MLS does not rely on any other system for its integrity.*

Separate integrity performance criteria are specified for Category I, II, and III operations.

The TRSB provides unambiguous output signals compatible with standard cockpit course-deviation indicators, digital indicators, and flight directors. Since it uses the same displays as ILS, the pilot does not have to assimilate new operational cockpit procedures.

The airborne equipment will automatically present a positive indication to the pilot of ground or airborne subsystem failure by warning flags and data displays. Monitor action will be initiated when any required guidance function or auxiliary data is absent or erroneous to a specified degree.**

TRSB ground monitors will:

a. Possess an automatic monitoring capability to detect out-of-tolerance conditions commensurate with each category of operations.

b. Provide warning to ATC and to airborne users (through the data channel) that the system is operating at a lower category of operation.

c. Terminate radiation if not within the tolerance of a lower category of operation.

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*Ref. 6, pp. 1-2.77 to 2.81 and 2-4.1
**Ref. 6, pp. 2-4.1 and 4.2.

Integrity relates to the trust that can be placed in the correctness of the information supplied by the facility and used by an aircraft. TRSB maintains a high degree of integrity by design features in the following areas:

a. Signal format

b. Interference reduction

c. Equipment monitoring

d. Multipath minimization

The TRSB integrity features are self contained and do not interface with outside elements of the ATC system except in the case of equipment monitoring which is remoted to indicators in the tower and maintenance facility. Automatic monitoring circuitry is an intergral part of both the ground and airborne equipment. TRSB relies primarily on the combination of field monitoring for an end-to-end integrity check of radiated signal at critical angles, supplemented by integral monitors for integrity and maintenance of the antenna and transmitter. These monitors provide an accurate indication of facility performance and status.

Overall functions of the monitoring system are depicted in Figure 11.1-6. Fault signals from any of the individual monitors initiate several actions in the Executive Controller. The first of these is to activate backup equipment, if it is available, or else shut down the faulty subsystem. At the same time, the Executive Controller revises the appropriate function status information displayed at the ground indicators, such as the control tower and maintenance monitor.*

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*Ref. 6, pp. 2-4.2 and 1-2.40 ff.
**Ref. 6, pp. 1-2.40.

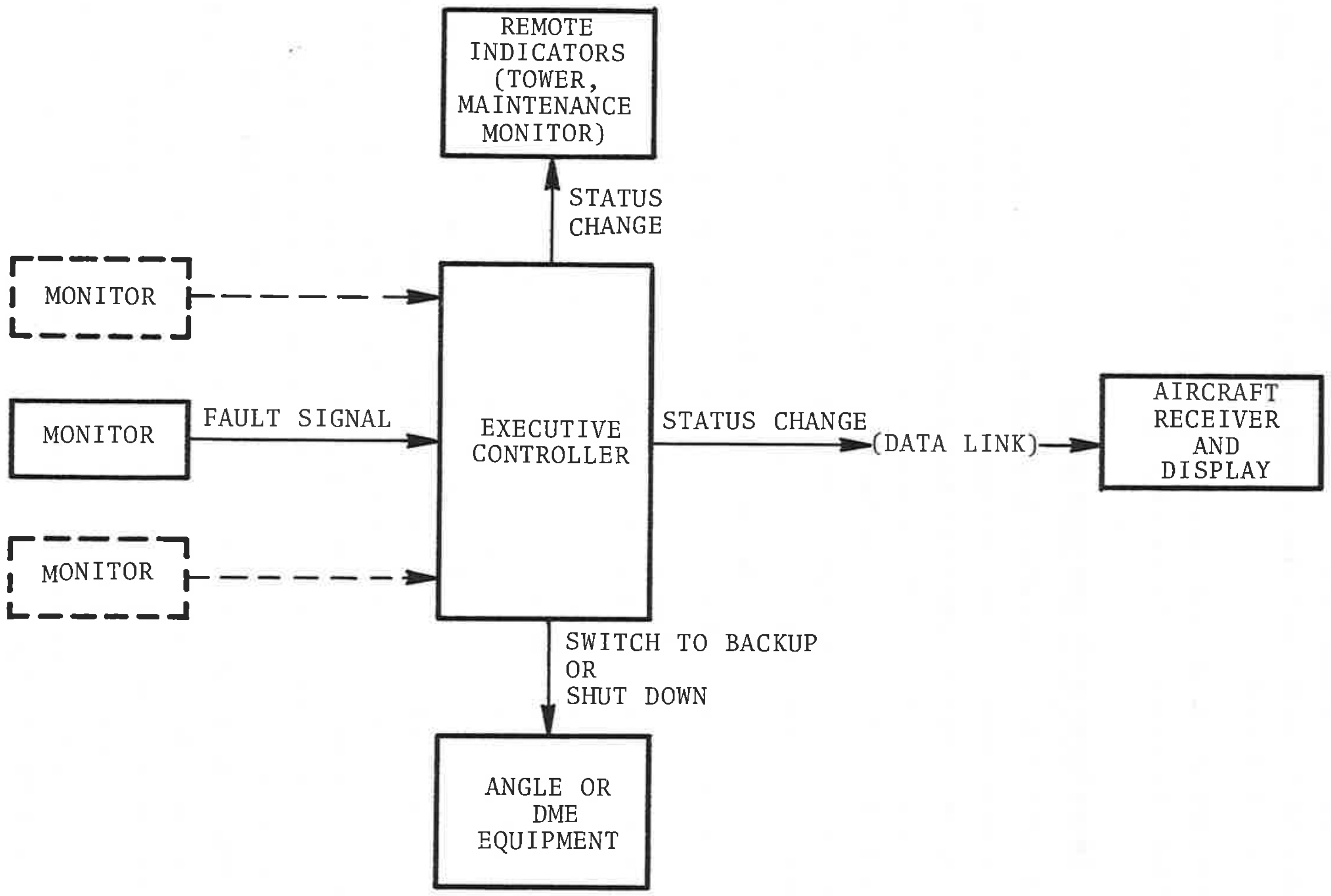

FIGURE 11.1-6. INFORMATION WHEN FAULT IS DETECTED*

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*Ref. 1, pp. 1-2.40

Airborne equipment monitoring is accomplished using Built-In Test Equipment (BITE) and the ground radiated test signal included in the signal format.

Examples of local and remote display functions in system monitoring are given in Table 11.1-2.

11.1.3 Interfaces With the Controller

The only direct interface between MLS and control tower personnel will involve the instrument panel for controlling and monitoring MLS, which resembles the current ILS panel in size and complexity. At locations having only MLS, the tasks required of the controller (probably the Local Controller) and the space occupied by the equipment should not differ significantly from their ILS counterparts in today's towers. Where both ILS and MLS are in use, the task and space requirements will be doubled. Since ILS monitoring and controlling takes a relatively small proportion of the controller's time in today's operations, this task increment will not be significant.

In the tower cab, the most significant indirect effects of introducing MLS will derive from the increased complexity of approach patterns that MLS makes possible. With ILS, the Local Controller basically looks for and reacts to departures of aircraft from a straight, narrow path in line with the runway. The introduction of short, curved approach paths and multiple glideslopes will greatly increase the complexity of perceptual judgments required of the controller in direct visual monitoring. With radar-generated PPI representations, standard curved approaches can be marked on the display to assist the controller. Even with this assistance, however, the estimation of arrival times at thresholds and time available to release a departing aircraft ahead of an arriving one will be more difficult for the controller than it now is with straight-in approaches, particularly with mixed ILS and MLS traffic.

TABLE 11.1-2. EXAMPLE OF LOCAL AND REMOTE CONTROL AND DISPLAY FUNCTIONS*

Item	AZ,EL & BKAZ Local Control/ Status	ATC Tower Cab Remote Control/ Status Panel	ATC Equipment Room Display Unit
AZ-EL-DME subsystem status indicators	Yes	Yes	Yes
AZ-EL-DME subsystem manual ON/OFF	Yes	Yes	-
Automatic shutdown (monitor activated)	Yes		Yes
Transient reaction time delay	Yes	-	-
Automatic restart (monitor activated)	Yes	-	-
Manual restart (monitor activated) 50 sec +5 sec, 1st step 5 min ±30 sec, 2nd step	Yes	-	-
Manual restart (Override of auto restart)	Yes	-	-
Fixed auxiliary data entry	Yes	-	-
Main power loss automatic restart	Yes	-	-
Primary power ON/OFF	Yes	-	-
Unit power ON/OFF	Yes	-	-
Manual local/remote control	Yes	-	-
Communications	Yes	Yes	Yes
Elapsed time meter	Yes	-	-
Station ID monitor	Yes	Yes	Yes
Aural downgrade alarm	Yes	Yes	Yes
Fault alarm silence switch	Yes	Yes	Yes
Lamp dimmer	-	Yes	-
Power source selection	Yes	-	-

---

*Ref. 6, Pp. 1-2.188.

It is not clear at this time whether the Approach Controller or the Local Controller will issue the final turn instructions for short, curved approaches. This consideration could impact the definition of jurisdictional boundaries and could conceivably add to the control duties of Local Controllers. In TRACABS, both Local and Approach Controllers will be in the cab; so in TRACABS the tasks associated with vectoring instructions will be a cab problem regardless of jurisdictional boundaries.

Provision has been made in the MLS design for ground-to-air transmission of such data as condition of runway, operational status of the guidance system, and weather data. Automation of this function will ease the Local Controller's workload. If such data cannot be generated automatically, it is likely that the preparation and entry of these messages would be assigned to the tower, probably to the Flight Data position. This function is similar to the current task of preparing ATIS messages. If this duty is added to the ATIS duty, it could cause a small, but undesirable, increase in tower workload.

When the full MSDP's are implemented, it may be possible to transmit aircraft-derived MLS position data to the ground via DABS as an input to surveillance and control functions. The automatic integration of this information with radar data increases the precision of automatic position monitoring and could lead to a reduction in the local Controller's workload. However, if the MLS-derived data were to be displayed separately and controllers required to make comparison with radar data and judgments of position accuracy, an undesirable increase in controller workload and an increase in data-tag densities on displays could result.

11.1.4 Failure Modes

Both Small Community and basic Category I MLS have but a single transmitter. The prescribed Category I minimums are such that a pilot experiencing a MLS ground system failure will have sufficient ceiling visibility to execute a safe missed approach procedure or to complete the landing. With a Category II system, the MLS has dual transmitters available but only one operational. The approach minimums prescribed allow for a safe go-around or landing during the switchover time. The Category III system is similar to Category II, however, unlike the Category II system, the backup system is kept operational for immediate switchover in the event of any indication of problems in the primary operating system. In the event of a ground system failure of either Category II or Category III system, minimums are temporarily raised and the system operates as if it were a Category I system until the problems are corrected and both transmitters are again available.

11.1.5 System Status and Development and Deployment Program

The Federal Aviation Administration's Office of Aviation System Plans (FAA/ASP) is preparing a transition plan for deployment of the Microwave Landing System. Industry participation in this effort has been maintained through the establishment of RTCA Special Committee 125(RTCA SC-125), which has prepared its own precision approach assessment. This RTCA assessment has been considered during the preparation of the FAA MLS transition plan. The transition plan considered alternative strategies for deploying the MLS and decommissioning the existing Instrument Landing System (ILS) to arrive at the strategy which would provide the most advantageous total landing system service throughout the transition period (nominally 1980-2000).

No final decision has been made as to whether the MLS will be widely deployed in the U.S. However, as part of the MLS transition planning process, the FAA and RTCA are assessing:

1) A requirements statement of what is needed, and when, to satisfy existing and forecast requirements for precision landing system service

2) An analysis of alternative means for meeting these requirements , and

3) An analysis of various strategies for implementing the selected alternative.

In July 1975 the FAA/ASP initiated the development of a methodology and model for use in assessing the benefits, costs, and other attributes of alternative implementation strategies for the MLS. An implementation strategy was defined as a sequence of options, together with a given budget for MLS ground system Facilities and Equipment (F&E) expenditures for each year of the transition period which would, in its own particular manner, accomplish essentially full deployment of the MLS and full decommissioning of the ILS by the end of the transition period.

Because of the complexity of the problem, a computer based model was developed to aid in estimating the benefits, costs and other significant aspects of alternative implementation strategies.[5] This model provides the flexibility needed to handle large volumes of data, accommodate complex interactions, and investigate the wide variety of alternative strategies and conditions to be considered. The major constraints on the model as finally developed include:

1) The model itself does not select a "best" implementation strategy, but it does produce information, such as benefits and costs, to enable the FAA to rank competing strategies

2) The model is not designed for assessing the tradeoffs between MLS and ILS, nor for detailed MLS site planning

Although the model has been applied to a number of alternative strategies, no decision has been made to date as to which, if any of the recognized and analyzed strategies would be selected. However, the transition plan tends to favor short term (1980-82) mid-term (1983-87) and long-term (1988-2000) strategies based upon a network concept. This approach permits creation of microsms of the total system about selected major hub airports served by wide-body aircraft.

Initial Phase (1980-1982)

- Install MLS's at new qualifier airports;
- Install MLS's at new qualifier runways;
- Co-locate MLS's with tube type ILS's;
- Install MLS's on runways with highest ranking AIA count (Baseline Deployment)

Phase II (1983-87)

- Install MLS's at new qualifier airports;
- Install MLS's at new qualifier runways;
- Co-locate MLS's with tube type ILS's;
- Upgrade eligible CAT I and II ILS runways with CAT II or III MLS"s,
- Baseline Deployment

Phase III (1988-2000)

- Install MLS's at new qualifier airports;
- Install MLS's at new qualifier runways;
- Upgrade eligible CAT I and II ILS runways with CAT II and III MLS's;
- Baseline Deployment.

The way that this strategy is formulated indicates that it lends itself to network or grouping of airports in each phase as suggested by RTCA. Therefore, it is further recommended that MLS installation priority be given to locations that form a network or grouping of airports. This is necessary in order to avoid installation of MLS ground equipment at isolated locations where avionic equipage would be minimal. It is also anticipated that in most cases the MLS equipment will be the "Basic" configuration rather than the "Small-Community configuration.

An F&E funding level of $20 million is anticipated throughout the transition period. Installed costs vary from some $214 thousand for a Small Community system to some $860 thousand for a Category III system. Consequently, from 25 to 90 systems could be deployed each year depending upon the mix of Small Community and Category levels. A total of approximately 1250 are expected to be deployed before the end of the transition period (the year 2000).

ILS facilities may continue to be installed through the year 1983; MLS systems will, of necessity, be co-located with ILS systems at many locations. Eventual phase-out of the ILS before the end of the transition period is a prime consideration implementation strategy assessment.

11.1.6 Issues and Comments

Interfaces With ICAO - The ICAO All Weather Operations Panel (AWOP) prepared an operational requirement for future landing guidance systems, based on the RTCA SC-117 report, which was presented to and accepted by the Air Navigation Commission. This requirement has scoped the efforts of development teams ever since. Although the ICAO requirement made no specific reference to microwave frequencies, most of the developmental effort centered in this frequency region.

Five nations made initial submissions to ICAO in 1973. These, with the techniques proposed, were the U.S. with Frequency Referenced Scanning Beam (FRSB) and commutated Doppler, the UK with commutated Doppler, Australia with Time Reference Scanning Beam (TRSB), West Germany with DME-based Landing system (DLS) and France with an integrated ATC system.

ICAO then established a working group (AWOP-6) to evaluate the technical submissions. The working group is comprised to ten members, eight of whom are technical representatives from Australia, Canada, France, West Germany, the Netherlands, the U.K., and the U.S., and the USSR. The other two members are from international groups - the International Air Transport Association (IATA) and the International Federation of Air Line Pilots Associations (IFALPA).

In February 1975 the U.S. terminated consideration of the commutated Doppler technique and concentrated its effort on the TRSB. Over time, the French effort waned and the remaining contenders are the U.S. and Australia with TRSB, the U.K. with commutated Doppler and West Germany with DLS. Selection of one of these contenders as the international standard system was expected in November of 1976, however the AWOP assessment of contenders was protracted. On March 18, 1977, AWOP-6 selected the TRSB MLS for consideration of the full ICAO membership as the preferred technique for International MLS. This recommendation is scheduled for consideration by the full ICAO membership in April 1978.

REFERENCES FOR SECTION 11.

1. Precision Approach System Transition Plan, Landing Systems Transition Plan Working Group, FAA/ASP, Draft Report,July 1977.

2. Report of the Department of Transportation Air Traffic Control Advisory Committee, December 1969.
3. A New Guidance System for Approach and Landing, RTCA-SC-117, December 1970.
4. National Plan for the Development of the Microwave Landing System, DOT, FAA, NASA, DOD, July 1971.
5. A Methodology and Model for Evaluating Implementation Strategies for the Microwave Landing System, Vol, II Supplementary Description, Material on file at DOT/TSC. October 1976.

6. U.S. DOT-FAA Proposal to ICAO "Time Reference Scanning Beam Microwave Landing System" Vol. I, II, FAA, Washington, D.C., December 1975.

APPENDIX B-1

VAS METEOROLOGICAL SUBSYSTEM SPECIFICATION

A meteorological data collection field subsystem (MDCFS) consists of a Rohn, SSV type, free-standing steel tower, three ambient wind speed and direction sensors, signal conditioning electronics for coverting sensor signal outputs to the appropriate form for transmission to a central microprocessor, electrical power conditioning equipment, and cabling. All equipment and installations shall conform to the appropriate sections of the following codes and regulations:

ANSI	- American National Standards Institute (Formerly ASA)
ASME	- American Society of Mechanical Engineers
ASTM	- American Society for Testing Materials
ETL	- Electrical Testing Laboratories, Incorporated
FAA	- Federal Aviation Adminsitration
IEEE	- Institute of Electrical and Electronic Engineers
IPCEA	- Insulated Power Cable Engineers Association
NAVFAC	- Naval Facilities
NBFU	- National Board of Fire Underwriters
NBS	- National Bureau of Standards
NEC	- National Electrical Code
NEMA	- National Electrical Manufacturers' Association
NESC	- National Electrical Safety Code
OSHA	- Occupational Safety and Health Administration U.S. Department of Labor Airport Design and Construction Standards
UL	- Underwriters' Laboratories, Incorporated

AASHO - American Association of State Highway Officials
- Local Building Code

1. Tower Location

The most desirable location for the placement of an MDCFS is approximately 1000 - 2000 feet from the runway threshold and 800 - 1000 feet to either side of the extended runway centerline. This is shown diagrammatically in Figure B.1-1.

These areas are chosen for two main reasons:

1) Data collected at various test sites has shown that vortices in the region between threshold and the middle marker are the most likely to stall in this approach area.

2) The MDCFS must be offset from the approach path so that the vortices themselves will not interfere with the ambient wind measurement instrumentation. Several factors can preclude the placement of the MDCFS at these locations including the following:

- Those areas not on airport property

- Too many relatively large obstruction, e.g., large buildings, trees, elevated roadways, etc., in the immediate area.

- Areas are located in water, e.g., most areas at Logan Airport.

- Area is located too close to the approach path of another runway.

If any of the above conditions are encountered the tower location can be modified, such as moving its location closer to the runway threshold, or futher to one side, depending on the terrain features in the approach region. Flat terrain obviously provides much greater flexibility in tower location. The services of a trained meteorologist will be required at difficult sites in order to insure the selection of a tower site which will not result in erroneous tower reading.

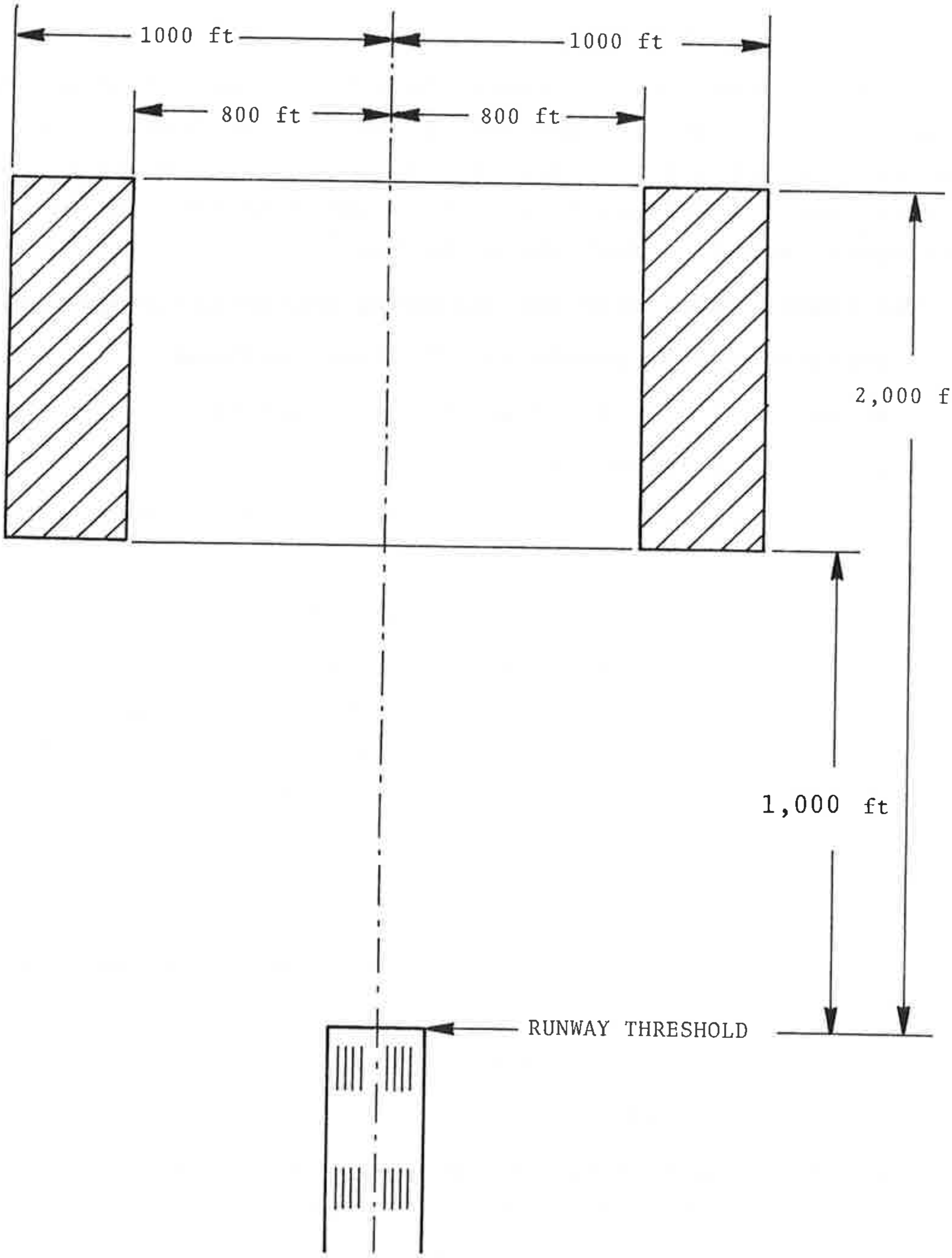

FIGURE B.1-1. MOST DESIRABLE AREAS FOR LOCATION OF METEOROLOGICAL DATA COLLECTION FIELD SUBSYSTEM

2. Tower Specification

Wherever possible all towers shall have a height of 50 feet. Two wind sensors shall be mounted at the 47 foot level and one wind sensor mounted at the top of the tower. The enclosure for the wind sensor electronics shall be mounted on the side of the tower approximately 4 feet above the base.

The towers shall have the following mechanical properties:

- designed for 30 pounds/sq. ft. load, minimum
- welded, hot-dipped galvanized construction
- must meet EIA spec. RS-222B
- painted international orange and white according to FAA standards

The towers shall have the following additional provisions:

- obstruction lighting kit, consisting of two lamps, red colored cover, 100 watts each, satisfying latest issue of FAA specification L-810, minimum 65 feet of #14 TW wire necessary conduit and junction boxes for wire run from top to bottom of tower.
- grounding rods: two 5/8-inch diameter, 10-foot long stainless steel ground rods at the opposite ends of a 10 feet square around the tower as shown diagrammatically in Figure B.1-2.
- climbing ladder with safety cable
- work platform at top
- lightning protection: a lightning rod, extending above the highest point of the top-mounted wind sensor will be installed with provision for an adequate connection from this point to one of the grounding rods at the base. Lightning masts shall be 1/2 inch diameter, 36 inches long, solid copper complete with base connector for down lead. Mounting clamp shall be adjustable tinned bronze for attaching to pipes through 2-inch outside diameter.

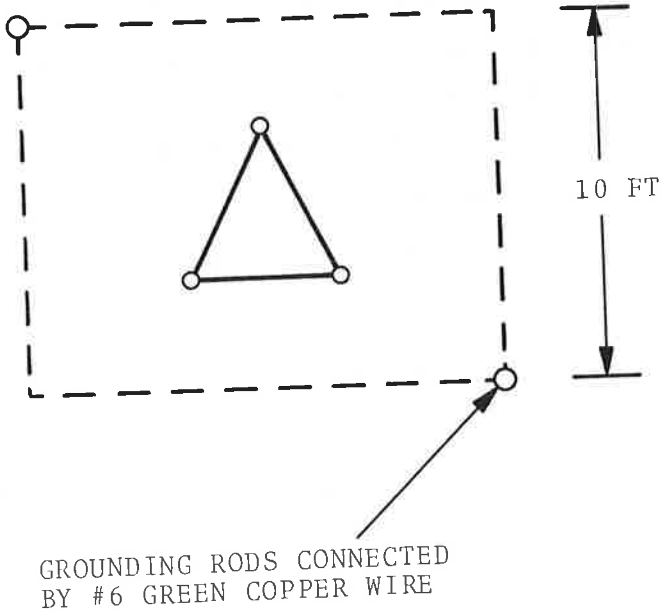

FIGURE B.1-2. GROUNDING ROD INSTALLATION

3. <u>Sensors</u>

The wind sensors shall be cup and vane type, and measure wind speed and direction at three locations on the tower as discussed in Section 2 above. Each sensor shall meet the following specifications:

a) Measure wind speed and direction.

b) Weight of tower mounted components less than 20 lbs.

c) Survive 160 kt winds in operating condition.

d) Mount on the end of vertical pipe.

e) Supply its output signal as a low impedance (100 Ω) dc voltage in the range 0 to 5 VDC with a one pole RC filter of 0.5-sec. time constant.

Wind speed sensor specifications:

f) Must be tachometer type sensor with no light bulbs.

g) Accuracy:

± 0.5 kts:	3 to 8 kts
± 1.0 kts:	8 to 20 kts
± 5%:	20 to 70 kts

h) Wind speed output shall be a linear voltage with range 0.00 to 5.00 VDC for a wind speed range of 0 to 128 kts.

Wind direction specifications:

i) Range of 0° to 360°.

j) Wind direction output shall be a linear voltage with range 0.00 to 3.52 VDC for the direction range 0° to 360°.

k) Distance constant shall be less than 50 feet.

l) Damping ratio shall be between 0.30 and 0.50.

m) Accuracy: ± 5°.

General Specifications:

n) A cable running from each sensor location to the electronics enclosure (Section 4) shall be supplied.

o) Reliability: Vendor shall furnish evidence of a mean-time-between-failure of at least one year (for the total speed-direction-transmitter package) based on data from at least 3 customers over a time of 5 years.

p) Tower mounted sensor components shall be designed for simple removal for replacement or maintenance.

3.1 Sensor Orientation and Calibration

The wind direction sensor shall be provided with a means to align its zero axis to magnetic north to an accuracy of 1°.

A separate calibration unit shall be used to calibrate each sensor. The unit shall tie into the output of the tower modem, allowing a calibration of the sensor, multiplexer and modem chain. The calibration unit shall apply a frequency or DC voltage corresponding to a specific input and sequentially reload the corresponding channel output, scaled in the units of the sensor under test, i.e., kts. or degrees.

4. Electronics Enclosure

The electronics enclosure shall house the transmitter cards for the six wind signals, an analog multiplexer, an A/D converter, a modem for transmitting the data to the central processor, all necessary power supplies and transient protection devices, and/or precision voltage reference.

General Specifications:

a) Sensor accuracies shall not be degraded under the following ambient conditions:

Temperature: -20°F to 110°F

Precipitation
Relative Humidity: 0 to 100%

Irradiation by summer sun.

NOTE: these specifications apply to the tower mounted components as well as the electronic components.

b) The enclosure and cable exits shall be weatherproof. It is expected that meeting specification a) will require maintaining at least the following internal conditions:

Temperature between 32° and 140°F

Relative Humidity between 0% and 95%

c) The electronics package shall be mounted on the side of the tower near the base. It shall be securely grounded to a grounding rod.

d) All lines to the tower mounted components and the modem output shall be protected against lightning surges with Tranzorb Surge Arrester Model 1.5KE7.5C or similar semiconductor device with voltage rating appropriate to the particular line.

e) DC power supplies operating on 115 VAC (normally at ±15 VDC and ±5VDC) are contained within the enclosure. The present power supplies shall be designed to disconnect the modem output when any one of the power supplies falls outside settable limits.

f) Total power consumption of the wind sensors and electronics enclosure shall not exceed 300 watts (115 VAC power).

g) Sensor transmitter and the A/D converter shall have convenient provisions for zero and span adjustments.

h) The electronics shall employ modular construction for ease in maintenance by card replacement.

5. Signal Processing

The 16-channel single-ended analog multiplexer scans through a selected number of channels at a rate set by the modem transmit rate. The sensor signals are assigned as follows:

MUX Channel	
1	Sensor 1 wind speed
2	" " " direction
3	" 2 " speed
4	" " " direction
5	" 3 " speed
6	" " " direction
7	2.5v ret
8-10	Power supply monitoring
11-16	Spares

Each MUX channel is selected in turn and digitized with 12-bit accuracy (5.000 VDC is full scale). The 12 data bits are combined with 4 bits of channel information to form a 16-bit word which is serialized and transmitted by the modem over a two wire cable to the central processor. The MUX-ADC unit currently used is Datel Model DAS16M12BA1B. The modem is Larse Model LCS-111-5440 which operates in a line switching mode at a crystal controlled 5440 Hz bit rate. Since 34 bits are required for each 16 bit word transmitted, the word transmission rate is 5440/34=160 Hz. When 10 channels are sampled, the sample rate is 16 Hz.

6. Power

Power is usually obtained from a Navaid site such as a localizer building, RTR site, etc. Each MDCFS is supplied and fused for 30 amps @ 240 volts which is distributed as follows:

> 20 amps @ 120 volts is supplied to a general duplex outlet which is used to power general service equipment such as scopes, soldering irons, voltmeters, etc.
>
> 10 amps @ 240 volts is supplied to a constant voltage transformer (e.g., sola model CVS) which satisfies the dual purpose of voltage regulation and transforming to 120 volts for use by the sensor electronics. This power

is then distributed through a lightning arrestor whose output is fused at 5 amps and supplied to the electronics package and to the obstruction lights. A schematic of this distribution is shown in Figure B.1-3.

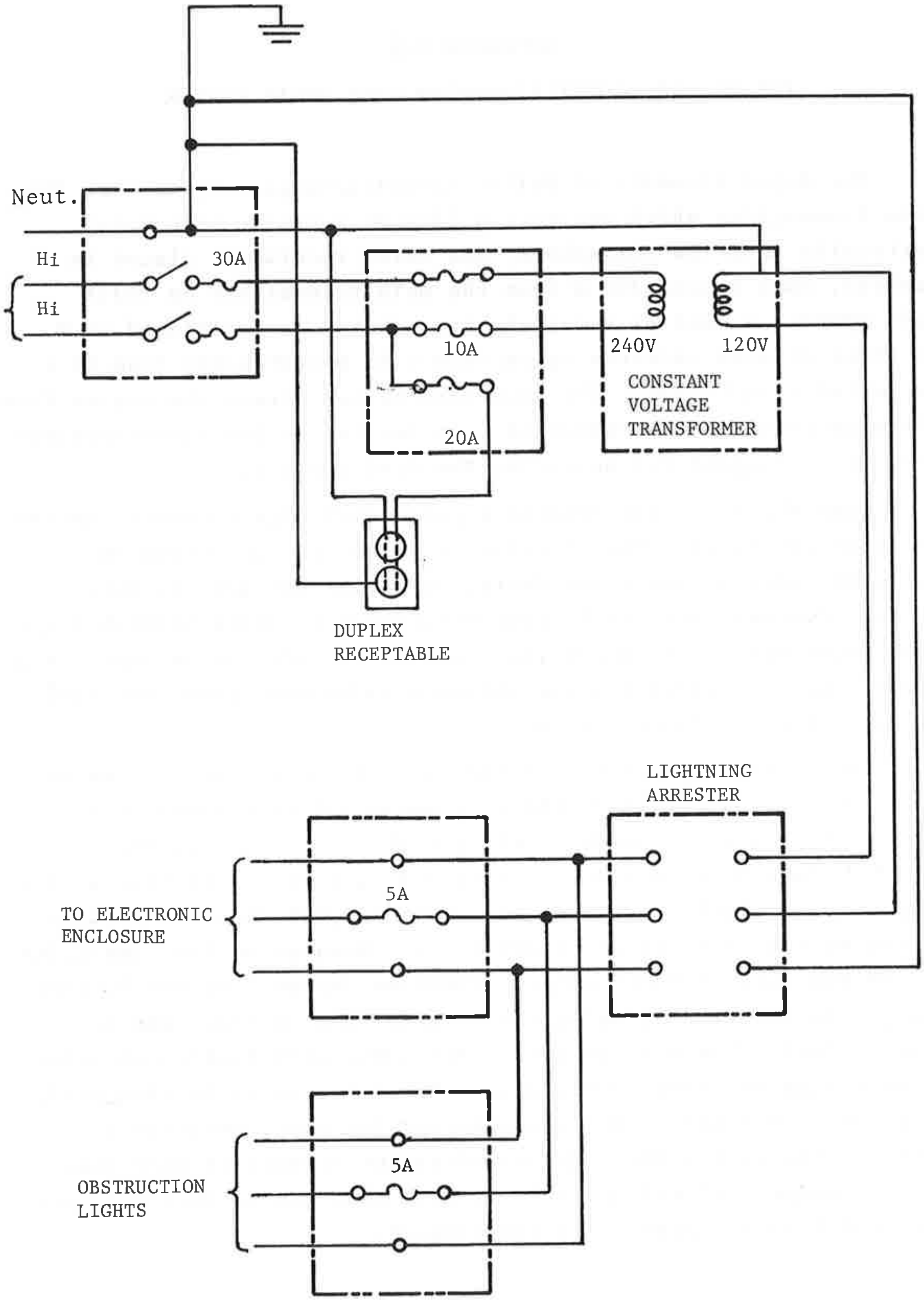

FIGURE B.1-3. POWER DISTRIBUTION

APPENDIX B-2

THE DULLES ACOUSTIC/DOPPLER WIND SHEAR SYSTEM

The major elements of Dulles Acoustic/Doppler system are the main transmitter which projects a 1750 Hz acoustic tone burst vertically into the atmosphere, and three receivers, placed in bunkers, each spaced 290 m from the main transmitter on radii 120° apart. A smaller satellite transmitter is positioned 50 m in front of each receiver to provide wind measurements from 30 m up to 150 m in height. The main transmitter covers the region from 150 m up to 500 m. Information from any two of the three receiver legs is sufficient for measuring the wind profile.

When the rain rate reaches a point that significantly impairs the acoustic system, the EM radar is automatically turned on. Its exact mode of operation during this time has not yet been fixed. However, the first tests employed a Velocity Azimuth Display (VAD) scan method for measuring the wind profile. Other operating modes, such as scanning along approach paths were also from both the acoustic and radar systems.

The central computer also processes the wind information to determine the magnitude of the wind shear and then relays these data to the airport control tower for display. As yet, the pressure jump detectors have not been tied directly to this central computer. A block diagram of the pressure jump detector portion of the system is shown in Figure B.2-1. Because of the simplicity of the pressure sensors' output, there may be no need for further processing before displaying the warning information. The test unit at Dulles has a large map of the area, with lights connected to each jump detector. When a segment of the array is triggered, corresponding lights come on displaying the exact position and shape of the gust front. By providing the controller with this type of output, he will be able to tell at a glance when a dangerous condition is approaching the airport.

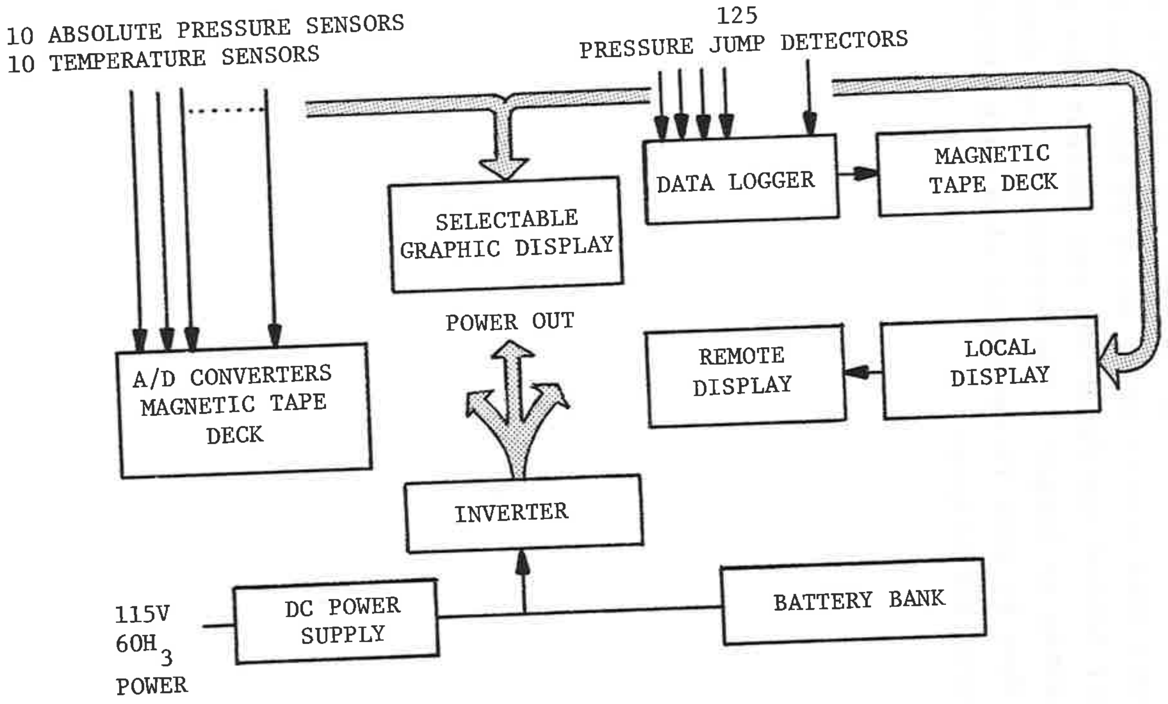

FIGURE B.2-1. BLOCK DIAGRAM OF PRESSURE JUMP DETECTOR SYSTEM

The total systems concept comes into play because the jump detectors can give only the location and speed of an approaching gust front. This would be sufficient information to issue a warning but would not provide the equally important all clear indication. After the gust front has passed the airport, it is likely that dangerous shears will still occur at the interface between the cold air behind the front and the ambient air aloft, possibly for 30 minutes or longer. The vertically profiling part of the system can then be used to determine when such shear conditions have abated over the airport.

APPENDIX B-3

TOWER CAB DISPLAY IMPROVEMENTS

Introduction

Newer, improved displays such as the NU-BRITE and Tower Cab Digital Display are being developed which will be more visible, reliable, and flexible in operation.

By video mixing, additional information, (e.g., tabular lists) can be placed in peripheral sectors of BRITE displays.

By programming the ARTS III computer, additional information can be displayed (e.g., tabular lists) on the TCDD, or on the ARTS III display.

Small digital displays, e.g., VAS display, will replace older instruments that took up more panel space.

Centralized vs Distributed Systems

Dependence on Central Processing or common displays for various functions has the drawback of single-thread reliability. To have a back-up system is often costly. VAS has distributed data processing, using 1 microprocessor per meteorological tower and uses one reliable-OR circuit to combine the outputs of 8 towers. The processed data is dispatched to a VAS digital display at each controller position, where each controller can dial up and receive information pertinent to a single runway. In this way one display or microprocessor going down will not pull down the whole system. A microprocessor board has a MTBF of 25,000 hours; in a system of 8 you can be expected to repair one in 3000 hours. A minicomputer has a MTBF of 5000 hours, but its down time is intolerable as the whole system would be down. The other advantage is that the microprocessors are inexpensive. They also reduce the number of components to be repaired.

Microprocessors are being planned for use in the SRAP, TCDD, and RDBM.

Better Utilization of BRITE Displays in CABS

Since the ARTS III-BRITE displays in cabs show tracked aircraft out of 30 nautical miles, much of the peripheral areas (e.g., the corners) can be used for the tabular presentation of information. For example, flight strip data can be video mixed and displayed. Similarly Wake Vortex Avoidance System information can be video mixed and shown on the ASDE-BRITE display. The information pertinent to each runway can be presented in the picture, at the end of the runway.

Vortex Advisory Systems (VAS)

Small alphanumeric displays indicating wind speed and direction, gust magnitude, and a condition for spacing all approaching aircraft at 3 nm will be installed in the Tower Cab of ORD by Oct. 1, 1977. There will be six displays of a controller type which can be runway-dialed (by the use of thumbwheels) and a supervisor type which gives all the information on all the runways.

Planned FY78 funding calls for the installation of similar displays at ATL, BOS, DEN, DFW, DTW, JFK, LAX, LGA, MIA, and SFO.

These displays are intended to replace the cab analog instruments for supplying wind magnitude and direction, monitored at a centerfield location. The displays will occupy approx. 18 square inches of panel space, which is a smaller area than the instruments, and they will supply meteorological information from points at the ends of runways as well as from the centerfield location. Six displays will be installed in the ORD Cab.

TCDD Tower Cab Digital Displays

In late 1977 four satellite airports, McDill AFB, St. Petersburg, Albert Whitted, and Sarasota, TCDD's will be installed which will interface with the Tampa ARTS III via modem links (4800 b/s except St. Petersburg which will be 9600 b/s).

The TCDD will present a full digital ARTS III type presentation on a display monitor suitable for viewing in a high ambient light situation (a 10 to 1 contrast ratio in a 450 foot-candle ambient). The data will be refreshed from a Remote Display Buffer Memory RDBM which is phone line connected to the ARTS III DPS. Data entry capability of the TCDD will be identical to that of the ARTS III display except that operational software will not allow reconfiguration, read ARTS III memory, magnetic tape flight plan input, update system and "OK" functions. The TCDD is plug compatible with the ARTS III Display, and thus can be used in central locations as well as at satellite airports.

The RDBM-TCDD combination for satellite airports will give the same type of radar presentation as the ARTS III displays at a lower price with a capability of being viewed in a higher ambient light condition and requiring only the transmission of change data through a voice grade line.

TABLE B.3-1. TCDD CHARACTERISTICS

1) Screen Size - 16 inches round

2) Address Matrix - 2048 X by 2048 Y for both radar and display coordinates

3) Range Scaling - 10, 15, 20, 30 and 60 nm hardware selectable

4) Offcenter - 1 radius maximum hardware selectable

5) Blink - capable of blinking any display data

6) Brightness Levels - Two distinguishable brightness levels, 200 ft. - lamberts maximum

7) Contrast Ratio - 10 to 1 in a 450 ft. - candle ambient

8) Vector Generator - Four textured vector line typed, solid, dashed, dotted, dot-dashed

   - 200,000 inches per second writing speed

9) Character Generation - Numerals 0 through 9, 26 capital letters of the alphabet, 18 special symbols and 10 non-printing control codes

   - 5 microsecond average writing time
   - stroke writing methods utilizing a minimum of 16 strokes for complex characters
   - three harware selectable sizes: 0.10, 0.125, 0.150 inches in height
   - Aspect ratio adjustable from 1:1 to 2:1

10) Conic Generator - Range rings at 2, 5 and 10 NM increments

    - 180 microsecond writing time
    - program selectable positioning for small circles and areas to represent special map symbols

11) Data Entry Devices - Two Remote ARTS keyboards, two trackballs and one control panel

12) Physical Characteristics:

    Display Monitor - 19 inches high, 19 inches wide, 27 inches deep

TABLE B.3-1. TCDD CHARACTERISTICS (cont.)

	- 85 pounds estimates weight
	- optional trunnion mounting
Control Electronics	- 30 inches high, 19 inches wide, 27 inches deep
	- modular mounting in a 19 inch rack
	- 100 pounds estimated weight

220copies

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