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DISCRETE ADDRESS BEACON SYSTEM (DABS) DATA LINK CAPACITY UTILIZATION: INTERIM REPORT

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INTERIM REPORT
NOVEMBER 1980

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16. Abstract

The Discrete Address Beacon System (DABS) will provide the basis for the automation of many air traffic control system functions envisioned in the near future, most notable amongst these being the Automatic Traffic Advisory and Resolution Service (ATARS). This document describes a set of services that may reasonably be expected to be provided by DABS in its first ten years of deployment. It establishes approximate capacity requirements placed on the DABS sensor and upper limits on the total amount of radio signals transmitted by the sensor in order to provide these services. The analysis is based on DABS and ATARS system definitions known as of July 1979. A final report, identifying exact DABS capacity requirements for providing these services, will be published at a later date.

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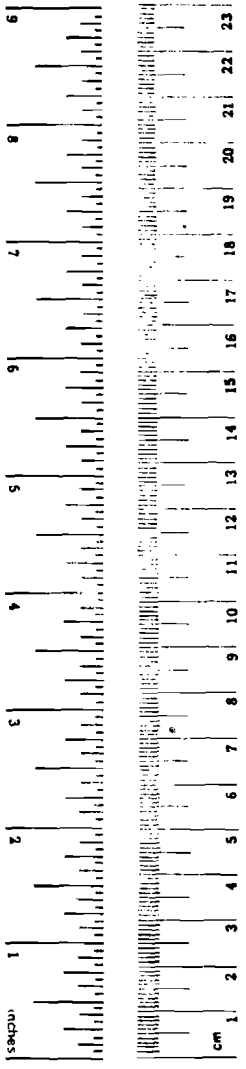
Approximate Conversions to Metric Measures

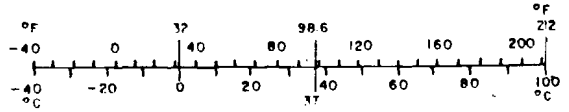
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



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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1. INTRODUCTION

The Federal Aviation Administration (FAA) is developing the Discrete Address Beacon System (DABS), in response to known deficiencies in the quality of surveillance obtainable from the existing Air Traffic Control Radar Beacon System (ATCRBS) and to satisfy current requirements to provide services such as automatic collision avoidance advisories which require the use of an automated data link between a ground Air Traffic Control (ATC) facility and the aircraft. These improvements can be provided by DABS by virtue of its improved surveillance system and through its integral data link. The DABS data link is derived from an exchange of radio signals between the DABS radar sensors and cooperative DABS transponders in the aircraft. There are many services in the aviation community that are today known or envisioned as possible candidates for using this data link to enhance the safety, capacity, productivity and the environmental and energy impacts of the air traffic system. Each service would imply a certain demand on the data link. System planners, of course, have to establish that DABS can support these services, and also establish that in so doing DABS would not create an interference with other communication systems that already exist and will continue to coexist with DABS. It is the purpose of this document to: (1) identify a set of services that may reasonably be expected to be provided by DABS in its first ten years of deployment; (2) to identify the requirements this places on the DABS sensor; and (3) establish the total amount of radio signals that the sensor will transmit in order to provide these services.

The first deployment of DABS sensors may be expected to cover major areas of air traffic activity in the United States. This document uses the mid-1990s time frame for estimating expected highest levels of system utilization. Projected services, expected DABS transponder and avionics equipage, and air traffic levels are all referenced to this time frame. These projections utilize information and models available as at the end of July 1979. In some instances recommendations for revised analysis have been presented.

The analysis is a "worst case" analysis in terms of the level of equipage and traffic environment, although it is not necessarily a "worst case" analysis in terms of the set of services required of DABS. Recommendation for revisions involve realistic lower traffic levels and imply lower utilization levels than those presented here. The results of this document are thus higher bounds for utilization and are

suitable for determining whether the deployment of DABS may present an interference to other existing systems. If signals at even such high utilization levels are found not to present unacceptable interference, then one can be sure that one will never reach unacceptable interference levels in actuality. For these very reasons however these results are not intended to be used towards establishing DABS data link capacity requirements since designing for these utilization levels would mean an overly conservative design. As discussed in Section 1.2 below, a forthcoming document (Reference 1) provides a refined analysis leading to a somewhat reduced utilization as compared to that presented in this document. Results of Reference 1 should be used for establishing DABS data link capacity requirements.

1.1 Outline of Document

Chapter 2 provides a description of the DABS data link. It describes how DABS performs its data transfer function. Chapter 3 identifies data link services that can reasonably be expected to be implemented by 1994. It also provides the data link usage in terms of messages per aircraft. Chapter 4 describes the environment in which these services would be expected to be provided. This includes estimates of the highest levels of air traffic expected to be reached by 1994 and the extent to which the aviation community would be equipped with the avionics necessary to be able to use the services being offered to them. Together, these lay the basis for computing the degree of utilization of the DABS data link. Chapter 5 contains these computation results. It provides histograms and charts of data link message rates for a traffic model for the Los Angeles Basin in the mid-1990s. It also includes histograms of advisories issued by the Automatic Traffic Advisory and Resolution Service (ATARS) in that model.

The overall findings of this study are summarized in Chapter 6. This chapter also includes a discussion of specific limitations of this study and recommendations for future work.

1.2 Expected Future Revisions

This study utilizes system features as known at the end of July, 1979: hence its characterization as an interim study. DABS and ATARS have been under active development, and many features have been revised since that time. These revisions have had a significant impact on overall sensor message rates and on message rates to a single aircraft, in general reducing the performance level expected of DABS. For this reason, a

revised analysis of the DABS data link requirements using these revised formats and features was necessary and will be presented in Reference 1. Notations have been included in this text wherever necessary indicating the particular features that have been revised.

Although Reference 1 thus supersedes the quantitative analysis presented in this document with respect to DABS data link message rates for the sensor and for single aircraft, the present document contains considerable other information relevant to the data link program which will not be included in Reference 1. This information is indicated below:

1. A detailed description of the set of candidate services for implementation via the DABS data link (Chapter 3).

2. A detailed analysis of ATARS traffic advisories in the Los Angeles basin air traffic model and their sensitivity to the traffic advisory logic thresholds (Chapter 5).

3. A graphical description of the azimuthal variation in DABS data link loading and its relevance to peak and average data link loading (Chapter 5).

The present document and the forthcoming Reference 1 are therefore companion documents.

2. DABS COMMUNICATION FORMATS AND PROTOCOLS

This chapter describes DABS data link communications. The discussion here is intended to give an understanding of the types of information transmitted and how this transmission is accomplished. More detailed descriptions of the DABS system and how it manages its data link can be found in References 2, 3, and 4.

2.1 DABS Signals

DABS signals consist of data messages sent from the ground sensor to the aircraft and messages initiated from the aircraft to be received by the sensor. These capabilities of the link are referred to as the uplink and downlink functions respectively. Uplink messages are transmitted at a rate of four megabits per second at a radio frequency of 1030 MHz and downlink messages are transmitted at a rate of one megabit per second at the frequency of 1090 MHz. The messages are bit streams, either 56 or 112 bits long.

A message always contains a 24-bit address which identifies the specific aircraft (transponder) with which the sensor is transacting. Surveillance is obtained by the sensor by sending a bit stream message called a surveillance interrogation which causes the transponder to respond with an appropriate message called a surveillance reply. The individualized nature of the transaction allows DABS to eliminate the crucial synchronous garble problem that the current ATCRBS system encounters in high density airspace. (See References 5 and 6). These individualized transactions also provide the means for transmitting DABS data link messages.

2.2 Basic DABS Messages

DABS contains provision for several message types to meet different data transfer needs. Table 2-1 describes the message types of interest here. The data link function always requires the 112 bit format. If no data is to be transferred, the short (56 bit) messages are used. (Current formats allow for some data bits in the short messages.) The standard uplink message is called COMM-A and the standard downlink message is called COMM-B. Both provide for 56 data bits and include surveillance information as part of the 112 bit message. This means that a COMM-A message can send 56 data bits to an aircraft and at the same time provide the surveillance interrogation necessary to elicit a surveillance response from the aircraft. The aircraft usually responds with a surveillance reply; however, it can

TABLE 2-1

DABS MESSAGE TYPES

TYPE	MESSAGE LENGTH (BITS)	INCLUDES SURVEILLANCE?	NUMBER OF DATA BITS	TRANSMISSION TIME* (MICROSECONDS)
UPLINK				
SURVEILLANCE INTERROGATION	56	YES	0**	18.5
COMM-A	112	YES	56	32.5
COMM-C	112	NO	80	32.5
DOWNLINK				
SURVEILLANCE REPLY	56	YES	0	64
COMM-B	112	YES	56	120
COMM-D	112	NO	80	120

*Uplink transmission on 1030 MHz frequency at 4 Megabits per second
Downlink transmission is on 1090 MHz frequency at 1 Megabits per second

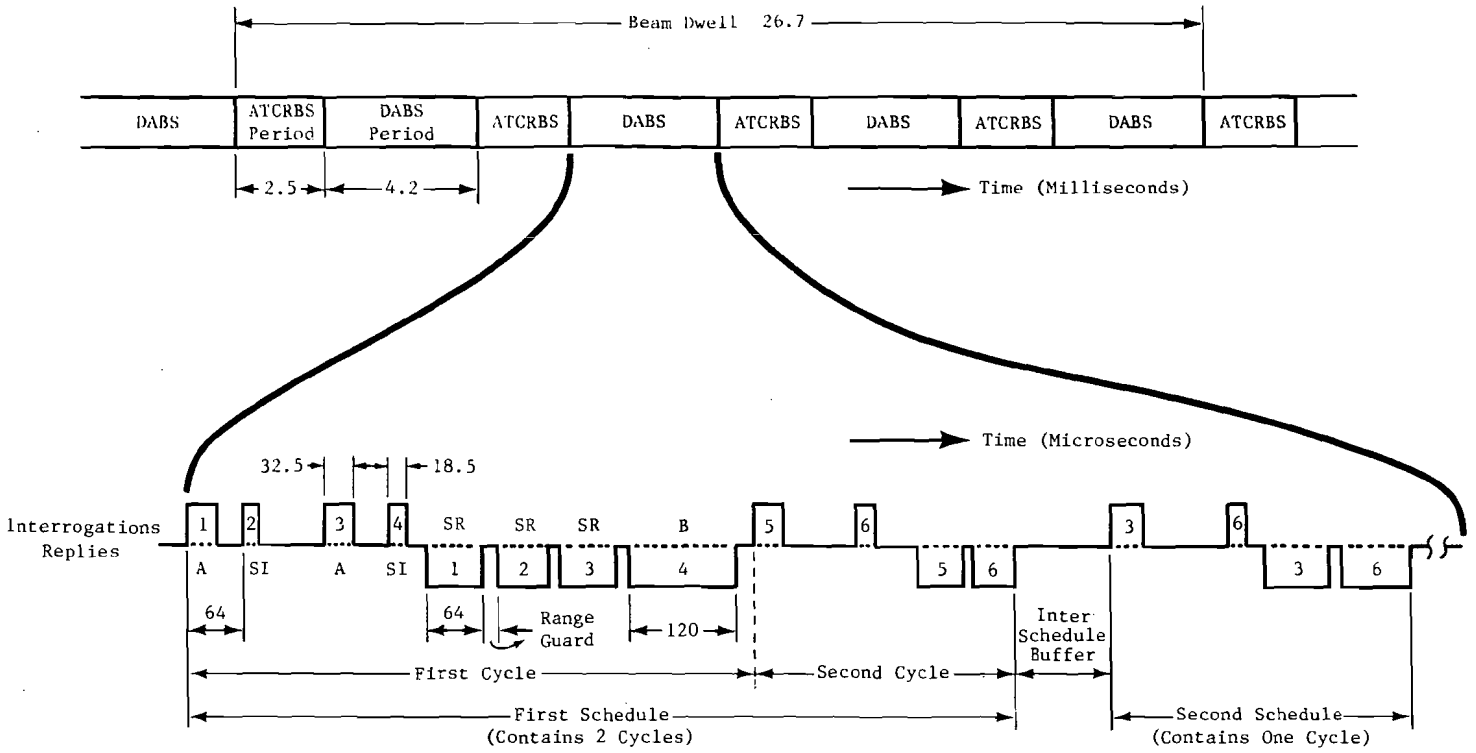
**Current system allows a few bits in surveillance transactions for minimum data link function

also respond with a COMM-B, which includes the necessary surveillance response. Both the surveillance and the COMM-A interrogations require and elicit a downlink response. If such a response is not immediately received by the sensor, the uplink message is repeated, usually while the radar beam is still passing over the aircraft. This provides for reliable surveillance as well as a responsive communication channel. Time critical data such as collision avoidance advisories can therefore be reliably sent via COMM-A signals. To understand just how DABS does all this, it is necessary to understand the way DABS manages its RF channel in real time. This is considered next.

2.3 Time Frame Management

The DABS sensor employs a rotating directional beam. All surveillance or other transactions with an aircraft must therefore be performed within the time that the beam is passing over the aircraft. This time is called the beam dwell and equals the ratio of the beam width to the angular velocity. The DABS beam width will be 2.4 degrees (3 db bandwidth). For a four second rotation period, the beam dwell will thus be 26.7 milliseconds (ms). The target population is composed of both DABS and ATCRBS transponders and DABS is required to service both types. DABS does this by providing a special ATCRBS/DABS all-call interrogation which provides surveillance on ATCRBS aircraft and also acquires DABS aircraft not yet known to the sensor. A part of every beam dwell is thus dedicated to ATCRBS/DABS all-call interrogations, its total duration being determined by the number of ATCRBS interrogations required and the "listening time" after each interrogation. Current ATCRBS sensors provide 10 to 15 interrogations per target scan. DABS, however, uses a monopulse system which can provide range and azimuth information in a single interrogation. It therefore requires fewer interrogations.

Figure 2-1 shows an example of how the DABS link is managed in real time during this basic unit of time, the beam dwell. This management is also called "scheduling." Each beam dwell period provides for four regularly spaced ATCRBS periods, interlaced with four DABS periods. Of the four ATCRBS interrogations, two are used for Mode-A information, and the other two for Mode-C information. As mentioned above, the same interrogations also provide the DABS all-call function. At any time within the DABS period, the sensor is scheduled either to perform an interrogation, or to listen to a reply or be idle. Suppose there are several targets in the beam. DABS first orders them in decreasing range order. The farthest target (target #1 in



Numbers 1, 2, ..., 6 Correspond To Targets

A = COMM-A Interrogation

B = COMM-B Reply

SI = Surveillance Interrogation

SR = Surveillance Reply

FIGURE 2-1
TIME LINE DEPICTION OF DABS SCHEDULING

Figure 2-1) is scheduled first. In this case a COMM-A is scheduled on the uplink eliciting a surveillance reply (RDLY + TDLY) microseconds later, where RDLY is the total (round trip) propagation delay which is known to DABS since the target range is known, and TDLY is a fixed transponder delay. (New targets unknown to the sensors are acquired in the DABS all-call/ATCRBS mode. The acquisition provides the sensor with the aircraft ID and position. The position of a known aircraft is updated each scan.) An interrogation and reply pair thus scheduled forms a transaction. The next transaction is scheduled for target #2 which is next in the range order. The interrogation is so scheduled that the reply to it will arrive immediately after the first reply, separated only by a range-guard to provide for the uncertainty in range due to the movement of the aircraft. Targets with smaller ranges are scheduled successively in a similar manner until there is no more room to schedule another interrogation (i.e., the next interrogation, if scheduled, would overlap the first reply). This group of interrogations and replies comprises a DABS cycle. A next cycle of transactions similar to the first one is then created and the process continued until all targets are exhausted. Such a set of transactions is called a schedule. In Figure 2-1, the first DABS schedule contains two cycles of four and two transactions respectively. A target is scheduled only once per schedule, since the current message must be successfully delivered before delivery of the next message is attempted for the same aircraft. If a message is not delivered in the current schedule (known by the absence of a valid reply) it simply gets repeated in the next schedule. If, after completing one schedule there are more messages to be delivered (whether new ones or repeats), another schedule is formed. Consecutive schedules are separated by an interschedule buffer. The length of the buffer interval is dependent upon the processing requirements for the schedule and of course upon the computing power of the sensor. More schedules are formed until all messages are delivered or until the available time for DABS scheduling in this period is exhausted.

More than 56 bits (the number of data bits in a single COMM-A or COMM-B) can be transacted in a single scan by utilizing a series of COMM-A and/or COMM-Bs. Surveillance, COMM-A and COMM-B messages are assigned high priority scheduling, which means that they are always delivered first, before attempting to transmit other messages. Data that is significantly longer or that does not require urgent delivery is transmitted via COMM-C's and COMM-D's, through a protocol called Extended Length Messages (ELM). This protocol is now described briefly.

2.4 Extended Length Messages (ELMs)

ELM messages are composed of COMM-C (uplink) and COMM-D (downlink) segments. It should be noted that a COMM-C and a COMM-A are identical as far as their radio frequency (RF) carrier characteristics are concerned. Both are uplink transmissions and are 112 bits long. They therefore occupy the same amount of time on the RF channel. Similarly, the COMM-B and the COMM-D are identical in their RF carrier frequency characteristics. Neither the COMM-C nor the COMM-D can, however, perform the surveillance functions. An uplink ELM message consists of several COMM-C's (up to a maximum of 16) and two COMM-D's for bookkeeping. (The overhead of two COMM-D's has since been revised in DABS.) Individual COMM-C segments of an uplink ELM do not require individual acknowledgements (i.e., a response from the transponder). A final COMM-C/COMM-D transaction keeps track of segments not received. Each COMM-C (including the "final" COMM-C) allows the transfer of 80 data bits. Thus, a total of 1280 bits can be transferred in one ELM. The individual COMM-C segments can be sent in any number of subgroups over several DABS periods or several scans if necessary. Since the individual COMM-C segments do not require acknowledgments, they can be transmitted every 50 microseconds. 50 microseconds is the minimum separation between two interrogations to guarantee resuppression of ATCRBS transponders in the beam. In the absence of any other constraints, this would presumably be the transmission rate used for COMM-Cs.

Except for the final COMM-C/COMM-D transaction, all other COMM-C's are scheduled in one or more "precursors" to the main schedules formed from the standard COMM-A/COMM-B/surveillance transactions. They are scheduled within the time left over from scheduling the higher priority COMM-A/COMM-B and surveillance transactions, although they are inserted at the beginning of the period rather than at the end. Figure 2-2 shows an example of scheduling an ELM to an aircraft. In this example the non-final COMM-C segments to the aircraft are shown scheduled in two precursors in two different DABS periods. The final COMM-C/COMM-D is shown scheduled in a following period and is part of a standard schedule. Depending upon the time available, the eligible periods may even belong to different scan times.

ELM transmissions are inherently more efficient than COMM-A transmissions when transfers of data longer than about 150 bits are involved and potential delivery delays of up to a few scans are acceptable. This means, that for the same amount of data

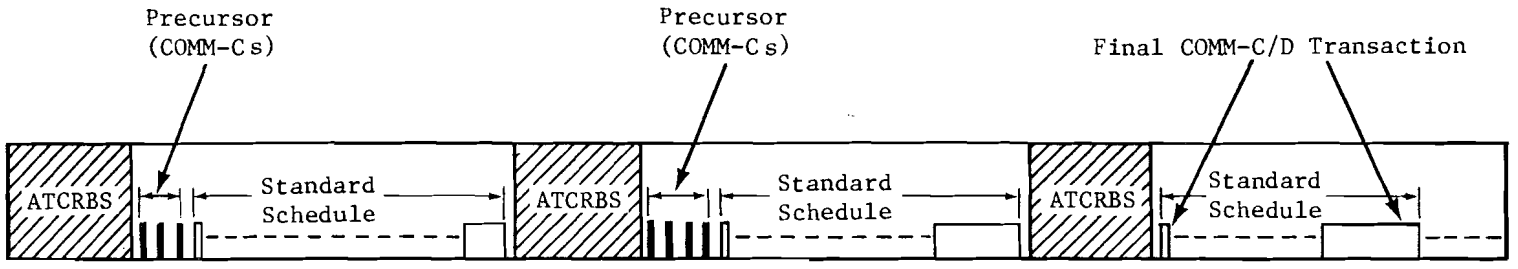


FIGURE 2-2
ELM SCHEDULING

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required to be transferred, an ELM always requires less RF activity, as long as the data is at least 150 bits long. It should also be noted that if the 50 microseconds interval between individual COMM-C segments should ever be of concern, that interval could conceivably be expanded to larger values. As already pointed out, it could not, however, be contracted to a much shorter value.

The uplink ELM capability requires logic in the transponder that is somewhat different from the one involved in the standard COMM-A or COMM-B transaction. A transponder which includes an uplink ELM capability would thus cost slightly more than one with a standard COMM A/B capability alone.

The downlink ELM protocol is similar to the uplink protocol, except that most of the transmission is downlink. If a capability for transmitting a series of successive long segments (COMM-D or COMM-B) is required of a transponder, its transmitter would need a larger power budget than that needed for a transponder with only a standard COMM-A/COMM-B capability. Providing for downlink ELM can therefore be an expensive proposition unless significant delays between COMM-D segments, (causing higher overall delays in the transmission of the downlink ELM) are acceptable.

The proposed DABS national standard (Reference 3) recognizes this difference between the uplink and downlink ELM capabilities and allows for the basic transponder to possess an uplink ELM capability without necessarily having a downlink ELM capability.

In summary, the uplink and downlink ELM protocols offer the potential of delivering significant amounts of data in a flexible manner. The major advantage of the ELM is that the transfer of the same amount of data through COMM-As or COMM-Bs would require much greater channel activity, both on the uplink and on the downlink since COMM-As and COMM-Bs require individual acknowledgements and provide for fewer data bits even though they occupy the same amount of channel time as COMM-Cs and COMM-Ds. Thus, for the same amount of data transfer, ELMs would create less interference to the ATCRBS system than the use of COMM-As and COMM-Bs. The price paid is that the delivery may be completed over a much longer time span (e.g., several radar scans). The extent of this delay is governed by the demand on the link and the design of the scheduler.

2.5 Summary

The DABS concept, in addition to its surveillance function, offers a data link capable of delivering multiple COMM-A and COMM-B messages providing for transfer of 56 bits or longer data, each scan. The DABS concept further allows for more efficient utilization of the link through its flexible ELM protocol. The ELM protocol can imply longer delivery time for messages. However, it requires less channel activity for a transfer of the same amount of data, when that data is significantly larger than 56 bits.

Theoretical analyses of the time line capacity of the DABS data link have been performed and show possibilities of great channel capacity. These results will be reported in Reference 1. Using the full time line capacity of the DABS RF channel implies packing messages densely along the time line, constrained only by considerations of radio propagation delays. Such packing involves considerable real time computing. Realizing the full theoretical DABS capacity thus requires correspondingly powerful and expensive computers and other supporting hardware.

A practical design of the DABS sensor will require providing for sufficient capacity so that the services that may reasonably be expected of the system during its life time will be deliverable. Chapter 3 addresses this issue. It identifies the services that may be expected of DABS in an extended time frame, and the requirements that each service will place upon the link in terms of messages per aircraft per scan.

3. PROJECTED DATA LINK SERVICES

The DABS data link will be the vehicle for providing many services which will contribute to the safety of aircraft, increase capacity of airports, increase controller/pilot productivity and which will facilitate procedures for maximum energy conservation. Probably the most notable amongst these future services is the provision of automatic collision avoidance advisories to aircraft. There are also many other services, such as the automatic transfer of ATC messages, that the data link will facilitate. Certain desirable enhancements in the current ATC system through increased automation would in fact not even be realizable without the availability of the data link to transfer data automatically to aircraft. It is the purpose of this chapter to identify services that may reasonably be considered to become available by the end of the first ten years of DABS deployment. This chapter also analyzes the requirements placed on the data link to provide these services to candidate aircraft. The manner in which these individual loads translate into a total sensor utilization is discussed in later chapters.

Table 3-1 lists the services considered likely to be provided by the mid 1990s time frame and the enhancements resulting from each. These services have been identified in this study by the author on the basis of known FAA commitments and development programs. This list is not an official FAA list. The set of services being considered by the FAA for implementation in the early years of DABS does however form a subset of the list proposed here (Reference 7).

A detailed discussion of each service is provided in the following. A summary of message transactions required by each service is provided at the end of this chapter. Avionics equipage requirements for each service are identified in a later chapter.

3.1 Automatic Traffic Adivsory and Resolution Service (ATARS)

ATARS is a software system that provides a traffic advisory service in routine as well as potential collision situations. Whenever two aircraft come into a potential collision situation, ATARS provides appropriate warnings directly to the DABS/ATARS equipped aircraft involved in the encounter and suggests a course of action. The service is not restricted to controlled aircraft; it is available to any DABS/ATARS equipped aircraft that is within coverage of the associated DABS sensor. The service also automatically provides aircraft with

TABLE 3-1

SERVICES EXPECTED TO BE AVAILABLE BEFORE 1994
AND THE RESULTING SYSTEM ENHANCEMENTS

Service	Enhancement			
	Safety	Capacity	Productivity	Energy Conservation
Automated Separation Assurance				
o Automatic Traffic Advisory and Resolution Service (ATARS)	X	---	---	---
o Provide Coordination Between ATARS and BCAS	X	---	---	---
Automation of ATC Services				
o Automated Minimum Safe Altitude Warning to Pilots	X	---	X	---
o Confirmation of Clearances for Routing, Departure, Altitude Assignment, Holding and Approach	X	---	X	---
o Voice Frequency Assignments For ATC Handoff Automation	---	---	X	---
o Advanced Metering and Spacing	---	X	X	X
o Automated Clearances	X	X	X	X
o Flight Plan Revisions	---	---	X	---

TABLE 3-1

(CONCLUDED)

Service	Enhancement			
	Safety	Capacity	Productivity	Energy Conservation
Other Services				
o Weather				
- Severe Weather Advisories	X	---	---	---
- Weather Information For Pilot-Requested Site	---	---	X	---
Digitized Weather Map	X	X	X	X
o Enhanced Terminal Information Service				
- Routine Terminal Information Including Runway In Use And Local Weather	---	---	X	---
- Environmental Updates And Alerts (e.g., Wind Shear, Changes In Runway Visual Range, Ceiling Or Visibility, Change In Runway, Change In Altimeter Setting, Sudden Temperature Or Pressure Drops, Etc.)	X	---	X	---
o Wind Profile Generation Through Downlinked Air-Data	---	X	---	X
o Redundant Navigation Through Uplinked Ground-Data	X	---	X	---

advisories on proximate traffic, identifying as "threats" those aircraft that are on a potential collision course. The system is presently under active development. This study uses the algorithms and data formats as known by July 1979. Reference 8 defines the ATARS algorithms and Reference 9 defines the DABS data link formats for transmitting ATARS advisories used in this study. These are discussed briefly in turn.

3.1.1 ATARS Advisories

An ATARS traffic advisory message is generated for two different types of encounters: proximity and threat. Proximity messages, named ordinary Proximity Warning Indications (PWIs) in the past, inform the pilot of all aircraft in the nearby airspace not currently viewed as threats. Threat messages (previously called flashing PWIs) are only sent to aircraft whose present flight path would bring them into conflict with the subject aircraft. The latter encounters are thus more urgent, and may require pilot action to avoid collision.

A proximity advisory is generated for any aircraft whose horizontal and vertical separations from the subject aircraft are both within specified limits. The vertical limit is always 2000 ft. The horizontal limit is equal to an approach range of 30 seconds at a speed which is approximately equal to the sum of the speeds of the two aircraft. This limit, thus grows with aircraft speeds, going beyond the minimum two nmi when both aircraft have speeds that exceed 120 knots. The limit is five nmi when both aircraft are traveling at 300 knots.

A threat advisory is sent when the other aircraft is closing in on the subject aircraft at a high enough rate to be of concern. Two time parameters called TH and TV are computed as follows:

$$TH = -(R2-DSQ)/DOT$$

$$TV = -(RZ/VRZ)$$

where R2 = Square of the relative horizontal range R
DSQ = A modification parameter computed dynamically
DOT = Vector "dot" product of R and VR, the relative velocity
RZ = Relative vertical range
VRZ = Relative vertical velocity

Although the actual criteria needed to create a threat situation are quite complex, an approximate simplification is

that all of the following three conditions must be met:

1. TH is within 50 seconds, or the current horizontal separation is less than 1.2 nmi; and

2. TV is within 50 seconds, or the current vertical separation is less than 900 ft; and

3. the projected horizontal closest approach range is less than one nmi.

ATARS resolution advisories are messages which advise the pilot of a recommended maneuver to resolve a conflict with another aircraft. These maneuvers are classified as follows:

Positive: Maneuver in a particular direction (Turn Right, Turn Left, Climb, Descend)

Negative: Stop an existing maneuver or don't maneuver in a particular direction (Don't Turn Right, Don't Turn Left, Don't Climb, Don't Descend)

Vertical Speed Limit: Limit the current vertical maneuver to a specified rate (500, 1000, 2000 ft/min)

Resolution algorithms are quite complex and are fully documented in Reference 8. A resolution advisory is always accompanied by a threat-advisory on the same aircraft.

The next section describes the formats and implied data link usage.

3.1.2 ATARS Formats

ATARS advisories, particularly threat and resolution advisories, are high priority messages. They are therefore designed to be packed in COMM-As. Although COMM-A messages have a 56 data bit field, eight out of these 56 bits are used for message type coding purposes. Thus, only 48 bits are actually available for data coding.

Reference 9 describes four alternate coding types. The second one of these four is considered in that document to be the most promising format. It is the only format considered in this study.

The proximity information is provided to aircraft in a format as shown in Table 3-2. It provides for the relative range,

TABLE 3-2

CODING FORMATS FOR ATARS PROXIMITY ADVISORIES

Field	Bits	Notes
Clock Bearing	4	1 though 12
Fine Bearing	3	3 3/4° lsb
Altitude Zone	2	above or below, coaltitude or not
Altitude Magnitude	3	see note
Range	6	0.2 nmi lsb
Heading	3	45° lsb, relative
ATC Control	1	in communication with ATC or not
ATARS Capability	1	equipped or not
"Most Critical" Flag	1	most critical advisory or not
	24	end of first message
Repeat of Above	24	second message
Total	48	

NOTE: If zone is "coaltitude", field is 100 ft least significant bit (lsb); otherwise field is 200 ft lsb from zone edge.

relative bearing and relative altitude of the intruder. It also provides the intruder's relative heading, ATC control status and ATARS equipage and sets a flag if this intruder is the closest in proximity. Information on two proximities can be packed in one COMM-A.

Information on a threat aircraft is uplinked by a separate threat message as shown in Table 3-3. It is seen that finer information, in addition to proximity information, is provided. In addition, considerable information about the point of closest approach is provided (Sections II and IV in Table 3-3). The entire message requires two COMM-As for transmission. (These formats have subsequently been revised to one threat advisory message per COMM-A.) Note that the message includes 11 bits for a conflict resolution advisory. An intruder declared to be in conflict is also always declared to be a "threat". Thus a resolution advisory is always uplinked in the threat message for that intruder. Resolution advisories therefore do not cause an extra data link load. (These formats have subsequently been revised so that resolution advisories now require a separate message.)

In addition to proximities and threat advisories, some other messages are also issued by ATARS under certain circumstances. An "own message" COMM-A is issued to aircraft periodically or at appropriate times to inform the aircraft of the parameters of motion being used by the system. In this analysis, this overhead is assumed to contribute one COMM-A every ten scans to an aircraft. Further, an additional COMM-A message is sent at the beginning and end of each encounter.

The DABS/ATARS system uplinks information on surrounding traffic as specified above. The concept does not specify display formats. Depending upon the individual needs of the user, some or all of this information may be displayed in a particular cockpit with the help of suitable display avionics. Potential display avionics range from very simple voice response system (VRS) type annunciators to very sophisticated cathode ray tube (CRT) type displays.

In summary, ATARS generates COMM-A messages for an aircraft informing it of the traffic situation around it. The exact number of COMM-A messages generated at any time to any aircraft is traffic dependent. Given the nominal ATARS logic (Reference 8) and the formats outlined above, these numbers can be computed for a sensor for any given traffic situation.

TABLE 3-3

CODING FORMATS FOR ATARS THREAT ADVISORIES

FIELD	BITS	NOTES
(I)		
Clock Bearing	4	1 through 12
Fine Bearing	3	3 3/4° lsb
Altitude Zone	2	above or below, coaltitude or not
Altitude Magnitude	3	see notes
Range	6	0.2 nmi lsb
Heading	3	45° lsb, relative
ATC Control	1	in communication with ATC or not
ATARS Capability	1	equipped or not
Most Critical Flag	1	most critical advisory or not
	24	
(II)		
Miss Distance	3	0.2 nmi lsb
Time to Closest Approach	4	4 s lsb
Altitude Zone at Closest Approach	2	above or below, coaltitude or not
Altitude Direction	2	level, climbing, descending
Turn Type	2	straight, right, left
Resolution Command	11	
	24	
(III)		
Track Number	3	1 through 7
Altitude High Order	3	1600 ft lsb from zone edge
Heading Low Order	4	2 13/16° lsb, relative
End Bit	1	
Velocity	7	10 knot lsb
Seconds of Time	6	1 s lsb
	24	
(IV)		
Clock Bearing at Closest Approach	4	1 through 12
Fine Bearing at Closest Approach	3	3 3/4° lsb
Altitude Magnitude at Closest Approach	3	see Note
Altitude Rate	5	200 ft/min lsb
Turn Rate	3	1°/s lsb
Encounter Status	2	to be defined
Most Critical Flag	1	most critical advisory or not
Miss Distance	3	
	24	

NOTES: Information requires two comm-As.
These formats have subsequently been changed. See Reference 1.
lsb = Least Significant Big
Altitude Magnitude Interpretation:
If zone is "coaltitude", field is 100 ft lsb
If zone is not "coaltitude", field is 200 ft lsb from edge

3.1.3 Cockpit Display of Traffic Informtion (CDTI)

This study does not include the use of a separate CDTI service in estimating the data link loading requirements on DABS. Appendix A explains the full justification for this. Briefly, known CDTI functions involve the display of positional data on proximate targets. Many of the proximal targets to be displayed for the CDTI functions are expected to be a subset of the ATARS proximities. Their resolution requirements are also similar. Appendix A shows that as far as data link loading is concerned, ATARS is expected to account for most of the loading requirements placed by CDTI functions. Some CDTI roles may, however, place a small additional load on the data link beyond that accounted for in this study. To that extent, data link utilization beyond that presented in this study will result.

3.2 ATC Services

The ATC system provides services to aircraft flying on IFR flight plans as also to those VFR aircraft that enter positive controlled airspaces such as the Terminal Control Areas (TCAs). ATC communication between controllers and pilots currently takes place entirely through voice channels. However, interference on the voice channel increases as the traffic densities increase. The data link provides a concurrent system through which highly reliable communication between controllers and pilots can take place. Besides greater reliability, the data link also provides faster delivery of emergency messages. Another FAA objective for future ATC systems is increased productivity through automation. Many of the possible advantages of increased automation in the ground system (e.g., automated en route IFR clearances) could only be realized fully when an automatic data link is available. In what follows, ATC services in the 1984 to 1994 time frame that may utilize the DABS data link are described. An analysis of data formats and the resulting data link utilization in terms of messages per aircraft is also provided.

The ATC system provides a controlled aircraft with altitude, heading, speed and radio voice frequency assignments associated with handoffs. These are described in Table 3-4. The type of data transfer involved for each type of assignment is also described there. This information is based on a detailed analysis presented in Reference 10 in connection with early efforts towards establishing data link requirements for the DABS system.

TABLE 3-4

ATC TACTICAL MESSAGES

MESSAGE TYPE[1]	DATA FIELD	
	Data Content	Data Range
Altitude Assignments		
Climb Now to and Maintain (Alt)	ddd	Zero to 99900 ft in 100 foot increments
Descend Now to and Maintain (Alt)	ddd	
Maintain Your Present Altitude of (Alt)	ddd	
Restrict Altitude Now to Between (Alt_1-Alt_2)	ddd-ddd	Zero to 99900 ft
No altitude assignment	--	(erase assignment)
Heading Assignments		
Turn Right Now to and Maintain (Deg)	ddd	Zero to 360 degrees in 1 degree increments
Turn Left Now to and Maintain (Deg)	ddd	
Maintain Your Present Heading of (Deg)	ddd	
Restrict Heading Now to Between (Deg_1-Deg_2)	ddd-ddd	Zero to 360 degrees
No Heading Assignment		(erase assignment)
Speed Assignment		
Increase Speed Now to and Maintain (Kts)	ddd	Zero to 999 Knots
Decrease Speed Now to and Maintain (Kts)	ddd	
Maintain Your Present Speed of (Kts)	ddd	
Restrict Speed Now to Between (Kts_1-Kts_2)	ddd-ddd	Zero to 999 Knots
No Speed Assignment	---	(erase assignment)
Voice Frequency Assignment		
Switch Now to ATC Voice Channel (Freq)	ddd.ddd	VHF and UHF Channels in 25 KHZ increments
Contact ATC Now on (Freq)	ddd.ddd	
No Voice Frequency Assignment	---	(erase assignment)
ILS Frequency Assignment	ddd-ddd	(same as above)
No ILS Frequency Assignment	---	(erase assignment)
Altimeter Setting Assignment		
Set Altimeter Now to (in. Hg)	dd.dd	26.00 to 32.00 in .01 increments

NOTES:

1. Message Type may be coded or translated into an appropriate display directive: e.g., "CLddd" for "Climb now to and Maintain ddd".
2. "d" equals one decimal digit. Period or hyphen indicates sub-field separators.
3. Excerpted from Reference 10.

In any given ATC environment the traffic is usually composed of a mixture of IFR and VFR aircraft. ATC messages issued to an aircraft depend upon the type as well as the phase of flight. Reference 10 develops the frequencies of ATC messages for each type of aircraft in various phases of flight. Some of this information was derived from an analysis of existing ATC practices, others from actual data gathered. Table 3-5 provides a summary of estimated messages issued by the ATC system to IFR arrivals and departures in a terminal controlled area (TCA). If the DABS data link were used to confirm each of the assignments, this will also represent the frequency of that usage. To an aproximation, this table would also provide the frequency of messages for an automated metering and spacing system. (If an automated metering and spacing system were operating, it would provide altitude, heading and speed assignments into and out of the terminal area. Those functions would not then be conducted manually. Thus, this table would still reflect the approximate total message rates when an automated metering and spacing system were installed.) The table shows that a typical arrival would receive about 1.3 ATC assignment messages per minute whereas a departure would experience about 0.8 ATC messages per minute. Aircraft in an en route environment would experience a lower frequency of ATC messages. Table 3-6, again based on information presented in Reference 10, shows that an en route IFR aircraft would receive about 0.32 messages per minute. This information was based on a peak traffic day in the Chicago en route center in December of 1968. Finally, Table 3-7 presents estimates of messages to VFR aircraft in controlled airspaces such as terminal controlled areas. It is seen that a VFR aircraft in a controlled airspace such as a TCA receives 0.3 ATC messages per minute.

Table 3-8 summarizes the above results on the probabilities of ATC messages transmitted to an aircraft in a terminal area. It lists all the aircraft categories discussed above that may receive ATC messages. The probability of receiving an ATC message per minute is translated into the probability of receiving a message on a given scan, assuming a scan time of four seconds. It is also necessary at this point to include an estimate of the number of aircraft in a traffic environment of interest eligible to receive each type of message. Chapter 4 describes the assumed traffic environment, the Los Angeles Basin projected 1995 model, and Section A.3 develops the number of aircraft in each category of interest. These numbers are used in Table 3-8 to facilitate an overview of message frequencies to controlled aircraft. Table 3-8 shows that the ATC system will issue an ATC message to a controlled aircraft

TABLE 3-5

SUMMARY OF TACTICAL UPLINK ATC MESSAGE RATES FOR IFR ARRIVALS AND DEPARTURES IN A TCA

Message Type	Number of ATC Messages Per Aircraft		Number of Minutes Under Control	Number of ATC Messages Per Aircraft Per Minute	
	Arrival	Departure		Arrival	Departure
Altitude Assignment	4	2	20	.20	.10
Altitude Confirmation	4	2	20	.20	.10
Heading Assignment	6	2	20	.30	.10
Speed Assignment	4	2	20	.20	.10
Voice Frequency Assignment	2	2	20	.10	.10
Altimeter Setting Assignment	1	1	20	.05	.05
Assigned Runway & Route Clearances	1	1	20	.05	.05
Ground Control	3	4	20	.15	.20
Take off Clearance Confirmation	--	1	20	--	.05
Enter Hold	.25	--	20	.02	--
Leave Hold	.254	--	20	.02	--
MSAW Advisories	0.05	0.01	20	.004	.001
TOTAL				1.294	.85

TABLE 3-6

TACTICAL UPLINK MESSAGE RATES FOR EN ROUTE IFR AIRCRAFT

	Overs	Withins
Altitude Assignment	.8*	3.1*
Heading Assignment	---	6.0
Speed Assignment	---	.2*
Voice Frequency Assignment	3.4*	3.0*
Route Clearances	---	2.0
Route Changes	.2*	.4*
Total Messages/Aircraft	4.4	14.7
Control Life (min)	59.3*	46.8*
Messages/Aircraft/Min	.07	.32

*Based on peak day Chicago ARTCC December 1968 (Reference 10)

TABLE 3-7

TACTICAL UPLINK MESSAGE RATES FOR VFR AIRCRAFT
IN TCA AND VFR HIGHWAYS

Message	Number of Messages/Aircraft In TCA or VFR Highway	Number of Minutes Under Control	Average Number of Messages/Aircraft/ Min
Altitude Assignment	1/Flight	20	.05
Heading Assignment	2/Flight	20	.10
Speed Assignment	1/Flight	20	.05
Voice Frequency Assignment	1/Flight	20	.05
Altitude Setting	1/Flight	20	.05

Total = .30

Based on Reference 10

TABLE 3-8

MESSAGE RATE SUMMARY FOR TACTICAL ATC SERVICES

Aircraft Category	Messages Per Aircraft Per Scan	Number of Aircraft
IFR Arrivals	0.086	57
IFR Departures	0.057	58
IFR Withins	0.021	141
IFR Overflights	0.017	22
Controlled VFR	0.02	528
TOTAL		806

WEIGHTED AVERAGE: 0.03 Messages Per Controlled Aircraft Per Scan

with a probability of 0.03 on any given scan.

Although a certain amount of coding can be, and probably will be, exercised for data link messages it is premature to assume any great degree of coding for ATC services at this point. One may expect that new ATC services will continue to be offered in the future. It is assumed in this study that a single ATC instruction can be uplinked in one COMM-A. It is assumed that five characters can convey the type of ATC command intended. Most ATC message instructions summarized in Table 3-4 contain three digits of information. Thus, eight characters would usually be required to transmit an ATC instruction. Reference 11 describes a six bit coding that may be used for text. A COMM-A will thus accommodate the required eight alphanumeric characters.

Another service expected to become available sometime before 1994 is automated clearances for IFR aircraft in en route airspaces (Reference 12). This service would benefit immensely from an automatic data link. Table 3-9 shows messages and examples of coding that illustrate this service. This particular coding scheme shows a use of character strings of up to 30 characters. To transmit a message such as this would require several COMM-As. The COMM-As would have to have an internal linkage. The probabilities of delivery of ATC clearances from such an automated system are not developed in this document. However, a larger, far more conservative estimate of the number of ATC messages per aircraft per scan is made to include delivery of such ATC messages. A ten-fold increase in the estimate already made is assumed. This yields a probability of 0.3 that a COMM-A would be delivered to a controlled aircraft on a given scan. It is assumed for the sake of this analysis that only one COMM-A is delivered on one scan for ATC message delivery and that if multiple COMM-As are required, they would be delivered on successive scans. As already pointed out, most ATC messages do require only one COMM-A for delivery.

The messages described so far require relatively prompt delivery (i.e., within a few scans). There are other messages, such as pilot originated flight plan revisions, that do not require prompt delivery. The pilot can request a revision by voice and the ground confirms this revised flight plan via the data link. Assuming a 100 character message per flight plan revision per one hour flight and a probability of revision of 20%, 20 characters would need to be delivered every hour. Such a message could be delivered via an uplink extended length message (ELM). Each ELM segment offers 80 data bits. Assuming

TABLE 3-9

EXAMPLES OF POSSIBLE AUTOMATED IFR CLEARANCES AND FORMATS

	AS DISPLAYED	CLEARANCE AS VOICED
ASSIGNED ALTITUDE WITH INTERIM CROSSING RESTRICTION	↓ FL999 x FRR ‡ FL999	DESCEND AND MAINTAIN AN ALTITUDE, CROSS A FIX AT OR ABOVE AN ALTITUDE.
	↓ FL999 x FRR † FL999	DESCEND AND MAINTAIN AN ALTITUDE, CROSS A FIX AT OR BELOW AN ALTITUDE.
	↓ FLL999 x 99 NW FRR ‡ FL999	DESCEND AND MAINTAIN AN ALTITUDE, CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT OR ABOVE AN ALT.
	↓ FL999 x 99 SE FRR † FL999	DESCEND AND MAINTAIN AN ALTITUDE, CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT OR BELOW AN ALT.
	↓ FL999 x FRR @ FL999	DESCEND AND MAINTAIN AN ALTITUDE, CROSS A FIX AT AN ALTITUDE.
	↓ FL999 x 99 NE FRR @ FL999	DESCEND AND MAINTAIN AN ALTITUDE, CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT AN ALTITUDE.
	↑ FL999 x FRR ‡ FL999	CLIMB AND MAINTAIN AN ALTITUDE, CROSS A FIX AT OR ABOVE AN ALTITUDE.
	↑ FL999 x FRR † FL999	CLIMB AND MAINTAIN AN ALTITUDE, CROSS A FIX AT OR BELOW AN ALTITUDE.
	↑ FL999 x 99 NW FRR ‡ FL999	CLIMB AND MAINTAIN AN ALTITUDE, CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT OR ABOVE AN ALTITUDE.
	↑ FL999 x 99 SE FRR † FL999	CLIMB AND MAINTAIN AN ALTITUDE, CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT OR BELOW AN ALTITUDE.
	↑ FL999 x FRR @ FL999	CLIMB AND MAINTAIN AN ALTITUDE, CROSS A FIX AT AN ALTITUDE.
	↑ FL999 x 99 SW FRR @ FL999	CLIMB AND MAINTAIN AN ALTITUDE, CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT AN ALTITUDE.
VECTOR HEADING TO INTERCEPT	TURN RIGHT TO 999 → FRR	TURN RIGHT/LEFT TO A HEADING AND PROCEED DIRECT TO A VOR.
	TURN LEFT TO 999 → J143	TURN RIGHT/LEFT TO A HEADING AND PROCEED TO INTERCEPT AN AIRWAY.
OVERTAKE OR HANDOFF ALTITUDE	X FRR @ FL999	CROSS A FIX AT AN ALTITUDE.
	X 99 NW FRR @ FL999	CROSS A DISTANCE AT A COMPASS DIRECTION FROM A FIX AT AN ALTITUDE.
	↓ FL999	DESCEND AND MAINTAIN AN ALTITUDE.
	↑ FL999	CLIMB AND MAINTAIN AN ALTITUDE.
SPEED CONTROL	REDUCE SPD TO 999 KTIAS	REDUCE SPEED TO VALUE NAUTICAL MILES PER HOUR INDICATED AIRSPEED.
	INCREASE SPD TO 999 KTIAS	INCREASE SPEED TO VALUE NAUTICAL MILES PER HOUR INDICATED AIRSPEED.
HOLD	HOLD NW 7ZD ON V4 LEFT 99	HOLD A COMPASS DIRECTION FROM A FIX ON AN AIRWAY USING LEFT/RIGHT TURNS AND SPECIFIED DISTANCE LEGS.

NOTES:

1. FL999 USED ABOVE 17,500 FEET MSL
   99 USED BELOW 17,500 FEET MSL
2. CLEARANCES INVOLVING FLIGHT PLAN RE-ROUTES ARE NOT SHOWN.

a 6-bit character coding, 20 characters would require two segments for transmission. It would only apply to IFR aircraft and could only be utilized by aircraft equipped for receiving uplink ELMs.

3.3 Weather Messages

Weather information is known to be an important factor in air safety. The pilot may make requests for a number of different types of weather products for a specific location (LOCID) of interest and DABS, in response, would uplink the weather information available to it from a National Weather Service data base via uplink ELMs. The following types of weather messages will be available: surface observations, terminal forecast, pilot reports, hazardous weather advisories and digitized weather radar maps. Except for digitized weather maps, all others will be transmitted in an alphanumeric text form. The digitized weather radar summaries are a semigraphical description of precipitation intensities for the area of interest. Formats for all these services are described in detail in Reference 11. Estimated message lengths and data link loading implementations for all weather messages except the digitized weather summaries are provided in the next section, along with similar estimates regarding the Enhanced Terminal Information System. Data link implications of digitized weather radar data are described now.

Reference 11 describes formats for providing a map of digitized weather contours to the cockpit from the ground. These formats provide for the display of a weather map digitized in a 22 nmi x 22 nmi grid. The weather map information (which includes a 6 level precipitation intensity in each 22 nmi x 22 nmi cell) is encoded using a four bit character set which allows alphanumeric and run length coding. A single 16 segment ELM can contain up to 300 such weather coded characters. Thus one ELM can provide weather radar information for an area of over 350 nmi x 350 nmi. A digitized weather map is assumed to be available to a pilot upon request. An aircraft equipped with an uplink ELM capability and an appropriate display device such as a CRT or a thermal printer would be eligible to receive digitized weather. All DABS aircraft are assumed to be so equipped. As a conservative assumption for data link sizing purposes, it is assumed that an aircraft may request digitized weather once every 15 minutes. An individual aircraft will thus receive four uplink ELMs or a total of 64 COMM-C segments, every hour.

3.4 Enhanced Terminal Information Service (ETIS)

Reference 13 describes the ETIS concept in detail. The ETIS concept consists of a variety of services including the delivery of weather data, airport status, various weather alerts and other advisories of benefit to the pilot in the terminal area. Many of these services are part of the existing Automated Terminal Information Service (ATIS) report which is transmitted continuously on specified voice radio frequencies. The primary enhancement seen in ETIS is that much of the information is capable of being continually updated, whenever warranted. If the pilot has initially so specified, particular data or changes in data are automatically dispatched at the point in the flight where they are so needed. Table 3-10 (extracted from Reference 13) describes the various ETIS messages and when they would be dispatched to aircraft.

The ETIS system will obtain much of its information related to weather from several systems currently under development by the FAA including Aviation Automated Weather Observation System (AV-AWOS) and Automated Low-cost Weather Observation System (ALWOS), both of which provide unmanned, real time reporting of surface weather conditions. These supporting weather systems are assumed to be available well before the year 1995 (Reference 13). Avionics accepting ETIS messages may be one or more of a large variety of possible devices, for example voice synthesizers, printers or CRTs . Uplink message formats may or may not depend upon avionics on board. This document makes conservative estimates about formats. It assumes that all eligible aircraft receive the longest possible messages in textual form.

ETIS messages are of two types: messages that are routine and can be delivered with a certain amount of delay and messages that are urgent and require prompt delivery. The urgent messages are discussed first. Changes in the altimeter setting, visibility, ceiling, and the runway visual range and alerts for wind shear, sudden pressure drops and thunderstorms are uplinked to an aircraft whenever necessary. These messages are time critical and require prompt delivery. They will be uplinked via COMM-A formats. It is assumed that each message will require one COMM-A.

In this document, conservative assumptions about the frequency of update of the urgent alerts are made. Suppose that a typical flight is divided equally in arrival, departure and en route phases. Suppose that each of the eight urgent messages described earlier is updated once every five minutes during

TABLE 3-10

ETIS MESSAGE TYPES

MESSAGE TYPE	CONTENTS	WHEN DISPATCHED
1. Initial Arrival ETIS	1,2,3,4,5,6*,7,10 11,12,16*,17,18, (8,9,13,14,15)**	Prior to arrival at entry fix.
2. Departure ETIS	1,3,4,5,6*,7,10,11, 12,16*,17,18, (8,9, 13,14,15)**	Upon pilot request
3. Final Approach	4* or 6*,7,8	Near outer marker or final approach fix
4. Change-Runways in Use	1	When changed
5. Change-Approach in Use	2	When changed
6. Change-Altimeter Setting	12	When value changes by pre-determined amount
7. Change-Visibility and/or Pricp. Type	4,5	When value changes by pre-determined amount
8. Change-Ceiling	3	When value changes by pre-determined amount
9. Change-RVR	6	When value changes by pre-determined amount
10. VFR Minimums	3,4	When conditions go below VFR minimums
11. NOTAM or Advisory	17	When put into effect
12. Wind Shear Alert	7,8,9	When detected
13. Pressure Jump Alert	12,13	When detected
14. Temp Drop Alert	10,14	When detected
15. Thunderstorm Alert	15	When detected
16. Pilot Request Response	As Requested	Upon receipt

MESSAGE CONTENTS

1. Runway(s) in Use (Approach and Departure)
2. Approach(es) in Use
3. Sky Condition
4. Prevailing Visibility
5. Precipitation Type
6. RVR
7. Center Field Wind
8. Runway or Sector Wind (Only for Runway(s) in Use)
9. Center Field/Runway Wind Vector Difference (speed, direction)
10. Temperature
11. Dewpoint
12. Altimeter Setting
13. Rate of Barometric Pressure Rise (___inches Hg in _____ minutes)
14. Rate of Temperature Drop (____ degrees F in ____ minutes)
15. Thunderstorm location, direction, speed (if available)
16. Density Altitude
17. NOTAMS and Advisories
18. Time of Day of ETIS Data

* If conditions warrant.
**Only when the associated alert is in effect.

Table extracted from Reference 13.

arrival or departure and once every ten minutes during the en route phase. This would imply that a one hour flight would receive ten updates or ten COMM-A messages for each type of alert. Thus the system would provide 80 COMM-A messages for the eight different types of alerts in an hour. This implies a probability of .09 COMM-A messages per scan per aircraft. It should be recognized that this is a very conservative estimate. Further, ETIS updates are only provided to aircraft specifically requesting update service at the time of the initial request for ETIS. In this study, all aircraft equipped with the necessary avionics are assumed to request this service.

Routine ETIS messages are now discussed. Table 3-10 shows several routine ETIS messages, for example the initial arrival ETIS, the departure ETIS, final approach ETIS, notices to airmen (NOTAMs), etc. Many of these messages are delivered to aircraft upon initial contact as an initial ETIS. None of them require prompt delivery. These messages can be fairly long. An estimate of the length of these messages is obtained from certain early studies conducted by the International Civil Aviation Organization (ICAO). Reference 10 presents the relevant data which is summarized in Table 3-11. It shows that, depending upon the type of request for weather or ATIS, the message may be 50 to 300 characters long. It is assumed here that, during a typical one hour flight in 1994, an aircraft may make one request of each kind shown in Table 3-11. At six bits per character, 12 characters can be packed in one COMM-C segment. So, the messages may require anywhere from four to 25 COMM-C segments as shown in Table 3-11. Since an ELM can be at most 16 segments long, a total of six ELMs accounting for a total of 60 COMM-C segments would be uplinked.

3.5 Downlink of Airborne Data

The success of an automated metering and spacing program as well as any other automatic clearance generation program depends upon a reliable knowledge of winds. The DABS data link provides a powerful means of generating wind profiles. Suitably equipped aircraft can downlink their airspeed and headings and the ground system, with its knowledge of the aircraft ground speed and track angle, can derive wind information. Table 3-12 shows a possible coding scheme for downlinking aircraft airspeed and heading. Such information from just a portion of the aircraft population would enable the generation of reliable winds in the airspace. Downlinking this information about twice every minute (from aircraft appropriately equipped - see Chapter 4) is considered sufficient. This service is assumed to become available by 1990.

TABLE 3-11

ESTIMATED LENGTHS OF ROUTINE ETIS TEXTUAL MESSAGES

Message Type	Uplink or Downlink	For One Hour Flight:			Number of COMM-C Segments	Number of ELMs
		Messages Per Flight	Characters Per Message	Characters Per Flight		
Noncontrol Advisories (e.g., ETIS)	Uplink	1.0	300	300	25	2
Ground To Air Weather (Enroute)	Uplink	1.0	250	250	21	2
Ground To Air Weather (Terminal)	Uplink	1.0	125	125	10	1
Terminal Update (ATIS)	Uplink	1.0	50	50	4	1
Total					60	6

Table is extracted from information in Reference 10
ATIS = Automatic Terminal Information Service

TABLE 3-12

WIND PROFILE GENERATION THROUGH DOWNLINK OF AIRBORNE DATA

Item	Bits	Unit	Range
Heading	10	0.5 Degree	0-360 Degrees
Airspeed	10	1 Knot	0-1000 Knots
Spare	28	-	-
Total	48		

3.6 Ground Data Uplinked to Aircraft

DABS could provide an aircraft with information on its range and bearing from either the DABS site or from one of a number of specified airports or fixes. Such information provides the basis for a redundant "distance measuring equipment" (DME) for those aircraft that already have a conventional DME. It also provides a cheap DME capability for those aircraft that don't already have one. Providing navigational information on what is otherwise a communication channel may seem to contradict the principle of separation between communication and navigation. In reality there is no such contradiction. Communication in the DABS data link is not compromised on account of this service because the channel management function of DABS, through its system of message priorities, assures that ATC and other urgent communication messages are always delivered before these other low priority messages. Navigation is certainly not compromised; on the other hand it is enhanced. The service is cheap because even a simple cockpit printer could satisfy its display requirements. Since a printer may be needed for other services also, the cost attributable to this particular service is potentially quite low. By providing the aircraft with its ground speed, considerable additional help in accounting for winds while airborne can be offered. This could offer a considerable improvement in navigation. By providing altitude above ground level, the aircraft is in effect provided a "poor man's radio altimeter." Table 3-13 shows data formats illustrative of such a service. It shows that the range and azimuth referenced to the site from which this information is being provided, altitude above ground level, and ground speed can all be provided within one COMM-A. Providing this data about every other scan is considered sufficient.

The data being uplinked for this service should be current data. Old data will effectively imply inaccuracies in position information. For example, a one scan delay in the data implies an error of about 800 feet for an aircraft travelling at 120 knots. This doesn't mean that the data necessarily needs to be uplinked frequently. It simply means that when it is uplinked, it should be current. For this reason, COMM-A transmission is assumed. These COMM-As should have "normal" priority. If due to extreme data link loading conditions, these ground data can not be transmitted on a particular scan, that information should simply be allowed to expire, allowing current data to be uplinked when the link is ready.

TABLE 3-13

REDUNDANT DABS DISTANCE MEASUREMENTS

Item	Bits	Unit	Range
Range	10	0.25 nmi	0-256 nmi
Azimuth	11	0.25 deg	0-360 deg
Site ID	8	--	0-256
Altitude (Above Ground Level)	6	100 ft	0-6400 ft
Ground Speed	9	1 knot	0-512 knots
Spare Bits	4		
Total	48		

Uplink of ground data for redundant navigation is not an official FAA candidate service being considered for early data link implementation. It is, however, included here by the author to illustrate future growth possibilities. The formats shown in Table 3-13 are also strictly for the purposes of illustrating its feasibility.

This service is assummed to be provided to every aircraft.

3.7 Summary of Services

Table 3-14 summarizes all services listed in this chapter. It identifies the DABS formats required for delivering the services and provides the frequencies with which each service is expected to be delivered to those eligible for it. ATARS message rate requirements can only be determined from exercising the ATARS algorithms on given traffic conditions. This is described in Chapter 5. Other services require COMM-A, uplink ELM or COMM-B transmissions as indicated. ELMs may be used for uplinking weather on request by site ID, or for uplinking routine ETIS or for uplinking digitized weather maps. As shown in Table 3-15, a total of 10 ELMs may be transmitted in an hour, accounting for a total of 124 COMM-C segments. Since there are a total of 900 4-second scans in an hour, this yields a probability of (10/900) = 0.011 that an ELM may be transmitted on any given scan to an eligible aircraft. The length of each ELM is different, depending upon the service. The average length, as seen from Table 3-15, is (124/10) = 13. No need is seen at present for downlink ELMs.

The actual load on a DABS sensor depends upon the target populations utilizing each type of service and their spatial distributions. These are discussed and analyzed in the next two chapters.

TABLE 3-14

SUMMARY OF SERVICES AND THEIR FORMATS

SERVICES		TYPE OF DATA LINK MESSAGES REQUIRED		FREQUENCY OF SERVICE (to eligible aircraft)
ATARS		Comm-As	2 Proximities per Comm-A 1 Threat in 2 Comm-As Also Overhead	Frequency Function of ATARS Logic & Aircraft Distribution
ATC	Urgent	1 COMM-A per Message		Probability 0.3 of a Message on Any Given Scan
	Record	Uplink ELM of 2 Segments		Once per 1 Hour Flight
ETIS & WEATHER	Urgent ETIS	1 COMM-A per Message		Probability 0.09 of a Message on Any given Scan
	Routine ETIS & Weather on Pilot Request	6 Uplink ELMs of Various Lengths +1 Comm-B per Request		Once per 1 Hour Flight
	Digitized Weather Radar Map	1 Uplink ELM of 16 Segments +1 Comm-B per Request		Once Every 15 Minutes
Redundant DABS-Navigation Through Uplink of Ground Data		1 Comm-A		Once Every 2 Scans
Wind Profile Generation Through Downlink of Air Data		1 Comm-B		Once Every 6 Scans

TABLE 3-15

UPLINK ELM MESSAGE LOAD

Service	Number of COMM-C Segments Per Hour To a Single Aircraft	Number of ELMs
Routine ETIS And Weather	60	6
Digitized Weather	64	4
TOTAL	124	10

10 ELMs per hour implies a probability of (1/15)*(1/60)*10 = 0.011 of an ELM per 4-second scan. The average number of COMM-C segments in an ELM is (124/10) = 13.

4. PROJECTED USER ENVIRONMENT

The data link utilization levels for any given sensor are determined by the number of aircraft utilizing each type of service which, in turn, is determined by avionics equipage. In addition, ATARS messages are also determined by the characteristics of surrounding traffic. This chapter identifies expected characteristics of the 1995 user environment: i.e., DABS equipage, other avionics equipage, traffic characteristics, and DABS sensor deployment.

4.1 Traffic Environment

Reference 14 presents expected DABS equipage in 1994 in terms of four classes of users. These are summarized in Table 4-1. Air carriers and high performance General Aviation (GA) aircraft are expected to be equipped with high cost avionics designed to meet ARINC specifications. Medium and low performance GA aircraft are expected to be equipped with less sophisticated low-cost avionics. The table also describes the user composition of each avionics class.

Table 4-2 presents national fleet forecasts and DABS transponder equipage for 1994. It is based on information in Reference 14. All classes of users except the class of low-performance general aviation aircraft are expected to be 100% equipped with DABS transponders. 71.9% of the general aviation aircraft are expected to be equipped with DABS transponders in 1994.

Table 4-3 summarizes expected dates of deployment of the services presented in Chapter 3 as well as their target populations as estimated from information available to the author. The dates of deployment presented are the earliest expected times that a service may become available with appropriate automation in the ground system. It is assumed that each target population would reach its final equipage level within five years after this service first becomes available. The equipage is supposed to proceed linearly over time. Of course, all aircraft receiving data link service must be at least DABS equipped. The target population column identifies the particular sub-population of all DABS equipped aircraft that are eligible to receive each service. The avionics requirements for each service (transponder and display avionics) are also identified. The population actually receiving the service then is that part of the DABS equipped target population that becomes equipped with the required display avionics by the year 1994. The following paragraph

TABLE 4-1

USER AVIONICS CLASSIFICATION

Class	Population	Description
A	Air Carriers	Redundant High Cost Avionics
B	High Performance GA - All turbine GA - 10% of Reciprocating Multi-Engine GA	(Non-Redundant) High Cost Avionics
C	Medium Performance GA - 90% of Reciprocating Multi-Engine GA	Low Cost Avionics
D	Low Performance GA - Single Engine GA	Low Cost Avionics (Those who do equip. Not all do)

NOTE: GA = General Aviation

Based on Reference 14.

TABLE 4-2

NATIONAL FLEET AND DABS EQUIPAGE FORECASTS FOR 1994

Class	Fleet Type	Total	New*	% of Fleet Equipped With DABS
A	Air Carrier	3,463	930	100%
B	High Performance General Aviation	19,200	9,800	100%
C	Medium Performance General Aviation	41,000	17,500	100%
D	Low Performance General Aviation	250,300	93,800	80% of New 67% of Old NET: 71.87% Are Equipped
	TOTAL	313,963		77.5%

* New aircraft are those commissioned after 1983.

Based on Reference 14.

TABLE 4-3

DATA LINK SERVICES TARGET POPULATIONS

Service	When Available (Expected Earliest Possible Date)	Target Population(2)	Required Avionics		Part of Target Population Assumed Equipped With Required Avionics By 1994
			Display Requirements	Transponder Capability	
ATARS	1984	All	ATARS Display	COMM-A	100%
ATC Services	1984	IFR and Controlled VFR	Alphanumeric(1)	COMM-A/B	100%
Digitized Weather	1984	All	Alphanumeric(1) or Graphical	COMM-B & Uplink ELM	100%
Etis & Routine Weather	1984	All	Alphanumeric	COMM-B & Uplink ELM	100%
Routine ATC (Flight Plan Revision)	1989	IFR	Alphanumeric	COMM-B & Uplink ELM	100%
Downlink of Airborne Data	1984	All	Sensors & Translators to Transponder	COMM-B	Avionics Categories A, B, and C
Uplink of Ground Data	1990	ALL	Alphanumeric	COMM-A	30%

(1): Anywhere from low-cost printer to sophisticated electronic display
(2): Service is only available to DABS equipped aircraft. DABS Equipage is determined by Table 4-2.

describes avionics equipage assumptions used in this study.

ATARS will become available with the first DABS site employed in late 1983. It is assumed that by 1994 every DABS equipped aircraft would be equipped with some kind of ATARS display, either a voice synthesizer or a basic ATARS display (such as that presented in Reference 8) or a sophisticated graphical display.

Automatic uplink of MSAW advisories, ATC clearance confirmations and automated metering and spacing instructions are all assumed to become available sometime between 1984 and 1989. Since good wind data is essential for automated metering and spacing, the capability to interrogate for and accept downlink airborne data is also expected to be available then. The many ETIS functions (including all the update functions) are also assumed to become available in 1984. Digitized weather radar data is assumed to become available sometime in the period 1984 to 1989. All of these preceding services require at least some kind of an alphanumeric display although more sophisticated alternatives may be used by some users. A low-cost alternative may well prove to be a heat-sensitive printer. A sophisticated alternative for the higher performance aircraft could be an electronic display. ATC services are high-priority messages and would be uplinked via COMM-As. Several services mentioned above would require the use of uplink ELMs. All DABS-equipped aircraft are assumed to have the capability of accepting uplink ELMs. This is a conservative equipage assumption and does not reflect the possible provision for several levels of DABS transponder capabilities with and without the capability to accept uplink ELMs. Downlinking of airborne data requires special sensors aboard aircraft and the ability to code the data from these sensors into a form acceptable to the transponder. Therefore, it is assumed that no low-performance (that is, single engine) general aviation aircraft would possess such capability. Automatic generation of flight plan clearances and flight plan revisions are assumed to become available in 1990. These would involve longer messages but their recipients already would be appropriately equipped. Finally, ground data for redundant navigation is also assumed to become available in 1990. It is assumed that the entire DABS-equipped population will get equipped to use that data in five years. Thus, in 1994, 80% of the population would be appropriately equipped.

We note that all our equipage assumptions are conservative. When deployment dates are uncertain, services are assumed to be deployed at the earliest date possible. Generally speaking,

the percentage of aircraft assumed to be equipped are liberal higher bounds.

A traffic model providing position and velocity information on each target is used for computer analysis so that target and message loads on any DABS sensor may be computed exactly. The Los Angeles basin was selected to represent the worst possible traffic situation. The model presented in Reference 15 was used as the model of peak traffic in the basin in 1994. It should be noted that the model in Reference 15 is designed to represent traffic in 1995. Using that model to represent traffic in 1994 is an overestimate of traffic conditions. The model described in Reference 15 is a snapshot of peak traffic in the Los Angeles basin. It is based on traffic projections made in the year 1972. The instantaneous airborne traffic count in the snapshot is 1840. This number is compatible with the number used in Reference 10 which is the latest FAA document using a model of the Los Angeles Basin in 1995 for planning purposes. This model is henceforth referred to as the LAX-1840 model. Besides providing specific position and velocity information on each aircraft, LAX-1840 also specifies aircraft user type, flight plan status (IFR or VFR), flight type (local or itinerant) and aircraft category (single engine, multi-engine, turbine, etc.).

It was assumed that DABS and avionics equipage ratios in the Los Angeles basin would be proportional to the national fleet numbers presented earlier in Table 4-2. LAX-1840 subtotals do not necessarily match these proportions. Therefore a mapping is made from the proportions of Table 4-2 into the LAX-1840 model. Table 4-3 shows that counts for IFR and controlled VFR traffic are required for estimating ATC service requirements. The DABS Transition Plan does not make estimates of traffic counts for controlled aircraft, nor does the LAX-1840 model contain categories to enable such estimates. These estimates were obtained from Reference 10, and mapped into the LAX-1840 model. A detailed discussion of all these computations is presented in Appendix B.

4.2 Sensor Configuration

The 1995 Los Angeles basin would undoubtedly be served by a network of several DABS sensors. The Engineering Requirements document (Reference 16) provides an example of an eight sensor configuration for the Los Angeles basin. Table 4-4 lists these eight sensors. The areas of jurisdiction for each sensor were determined by a simple "bisecting-line" algorithm. This means that the boundary between two sensors is the perpendicular

TABLE 4-4

DABS SENSORS ASSUMED TO SERVE LAX-1840

Number	SENSOR
1	Norton AFB
2	Ontario
3	El Toro
4	Santa Ana
5	Long Beach
6	San Pedro
7	Los Angeles International
8	Burbank

bisector of the line joining the two sensors. Outside boundaries were determined by assuming seven more sensor locations outside the L.A. Basin to yield the jurisdiction map shown in Figure 4-1. Figure 4-1 shows locations of the eight sensors, the jurisdication maps of each sensor, the position of each aircraft in the LAX-1840 snapshot and the shoreline. Each sensor is assumed to be responsible for all aircraft (and only those aircraft) within its jurisdiction.

In summary, the LAX-1840 model described in Reference 15 is used as the traffic model on which to exercise the expected DABS data link services to obtain exact data link loading counts in the 1994 time frame. Proportions of aircraft users, aircraft type and equipage conform to national fleet equipage projections made in the DABS Transition Plan (Reference 14). Eight sensors are assumed to service the traffic. An analysis of the sensor loading requirements in this environment is the subject of the next chapter.

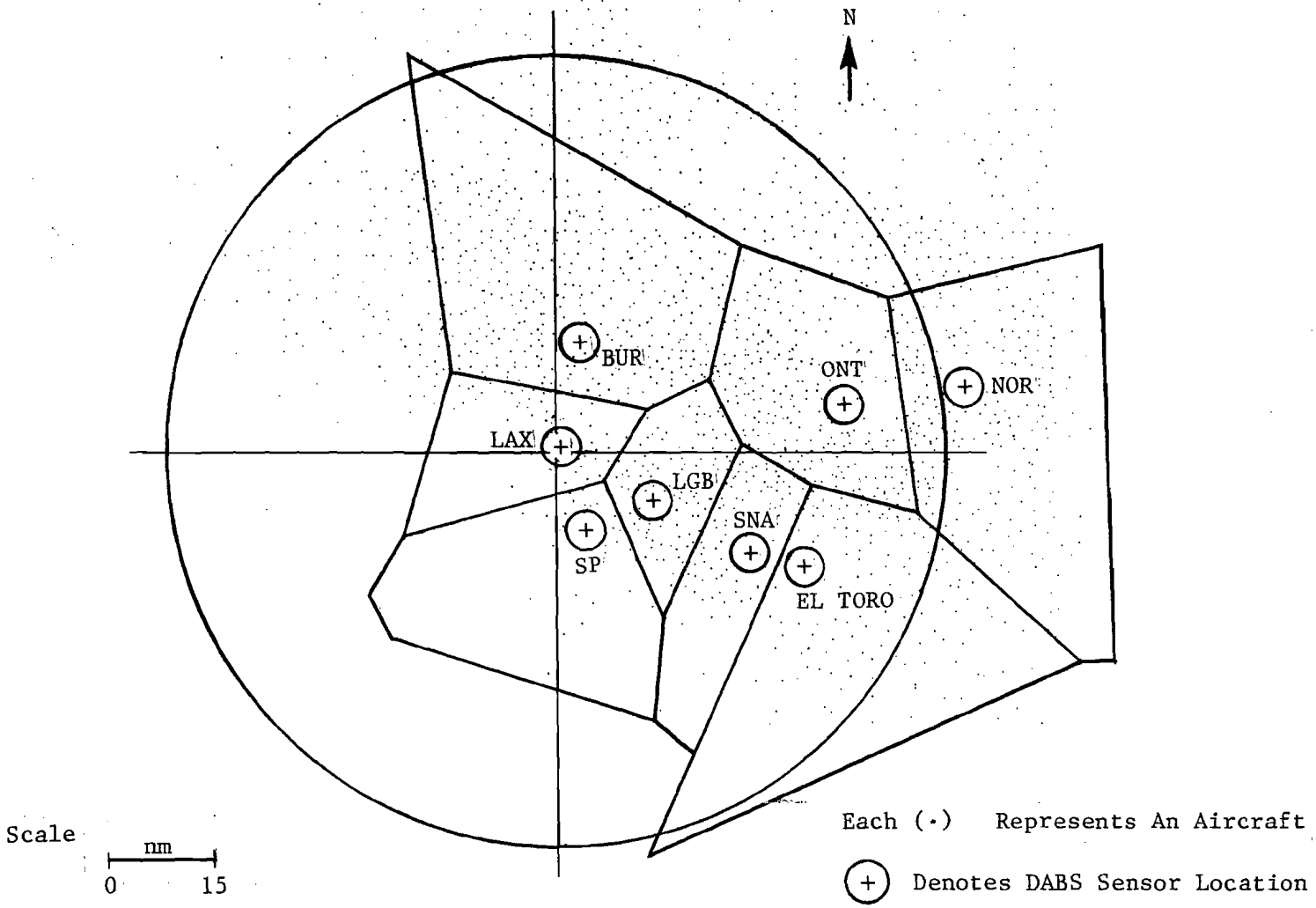


FIGURE 4-1
INSTANTANEOUS AIRBORNE AIRCRAFT AND DABS COVERAGE IN LAX-1840

5. DATA LINK LOADING

This chapter presents counts and histograms of DABS uplink and downlink messages in the 1995 Los Angeles basin. These are presented for all of DABS sensors assumed to be deployed in the Los Anglels basin by 1995. A closer look is also provided of ATARS message rates.

5.1 Methodology

Two computer programs, named "DUA" and "BUNCH", incorporate all the data link loading considerations presented so far. They accept an aircraft file and a sensor jurisdiction map as inputs and they output data link loading for any designated sensor. Figure 5-1 shows the flow of computation. Program DUA accepts the LAX-1995 data set and first labels each aircraft as DABS equipped or DABS unequipped. Appendix A shows that 31% of the Single Engine aircraft in LAX-1995 should be labelled unequipped. A random number generator is used to implement this labelling. Next, the program DUA exercises the ATARS algorithms of Reference 8 on the entire model. Most ATARS parameters are set to values indicated in Reference 8, except for the changes shown in Table 5-1. The look ahead parameters (TFPWI, TCMDH, and TCMDV, all with UUIND = 2) apply to encounters between two uncontrolled aircraft where one of them is unequipped and the speed of the equipped aircraft is less than 1.5 times the speed of the unequipped aircraft. The original parameter values for such encounters provided more than 30 seconds extra time above and beyond that allowed for the case when both uncontrolled aircraft are equipped (see Reference 8). This extra time was considered excessive by the author. After discussions with designers of these parameters (authors of Reference 8) the values were reduced as shown in Table 5-1. The new values provide eight extra seconds compared to the case of both uncontrolled aircraft being equipped. A discussion of the reduction in the value of RDIST is postponed until later in this section.

The program DUA outputs a file which contains, for each aircraft, its DABS equipage status and a count of ATARS traffic advisories (threats and proximities) to be issued to it. Commands are not computed since they form a subset of threats, and information for any commands issued is included in a threat message in the ATARS formats used for this study.

Program BUNCH accepts this intermediate file of all the aircraft in the basin. It also accepts a map of the sensor's jurisdiction. Input parameters specify a sensor of interest.

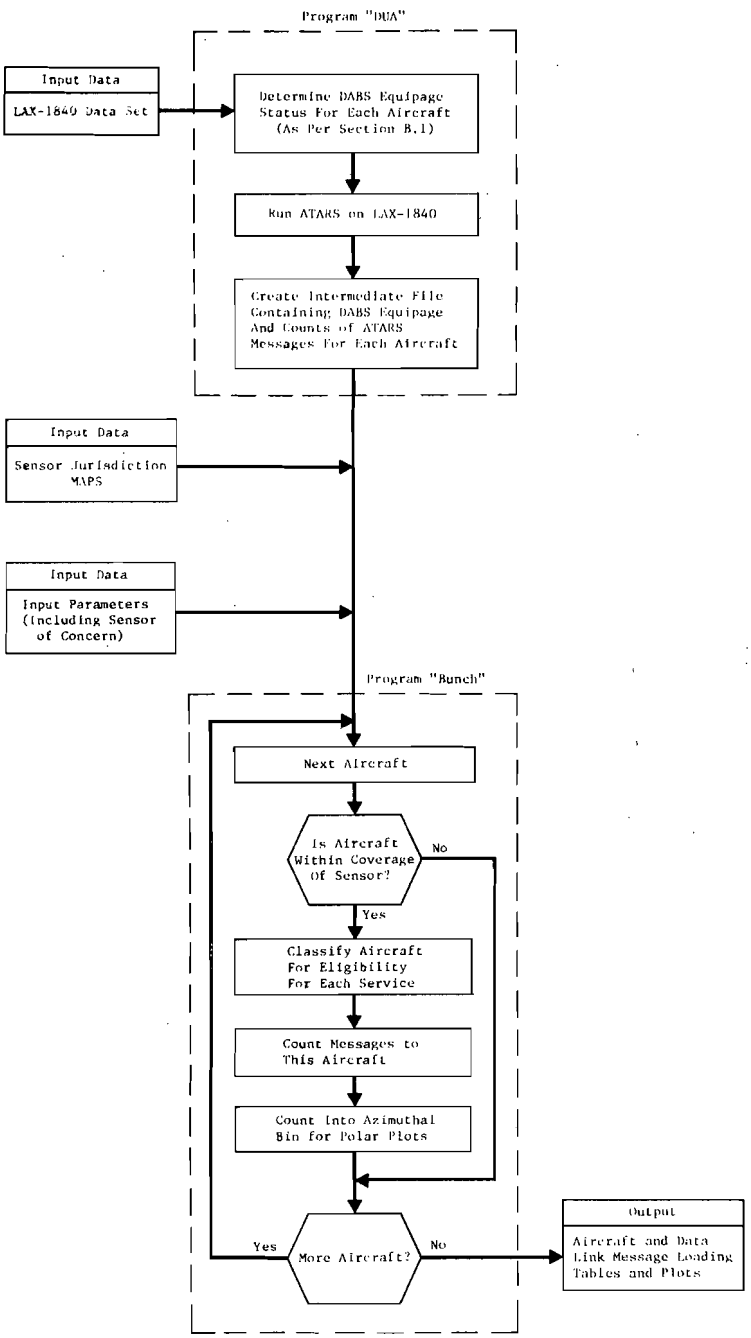


FIGURE 5-1
DATA LINK LOADING: FLOW OF COMPUTATION

TABLE 5-1

PARAMETER VALUE DEVIATIONS FROM NOMINAL ATARS*

Parameter	Value in Reference 8	Value Used in This Analysis
RDIST	50 nmi	100 nmi
TFPWI (UUIND = 2)	75 s	53 s
TCMDH (UUIND = 2)	64 s	40 s
TCMDV (UUIND = 2)	64 s	40 s

* Reference 8

The program BUNCH processes the aircraft file on a per aircraft basis. It first determines the aircraft membership in the sensor jurisdiction on the basis of the input maps. If the aircraft lies within the sensor's coverage limits, it proceeds to classify it for "eligibility" for receiving each service. "Eligibility" simply indicates that the aircraft belongs to a subpopulation which may receive that particular service. Chapter 4 and Appendix A develop these eligibilities in terms of percentages of specific subpopulations. A random number generator is therefore used where appropriate to label each aircraft for service "eligibility". Finally, the program BUNCH actually computes messages to each aircraft depending upon the probabilities of receiving each service as summarized in Table 3-14. ATARS messages are not computed in BUNCH since they are already available to BUNCH from the intermediate file.

The explanation for the change in the value of the parameter RDIST from 50 nmi to 100 nmi can now be provided. In reality, ATARS messages would actually be generated at each of the eight individual ATARS sites for their respective jurisdictions. In this particular deployment, each ATARS jurisdiction is wholly contained within 50 nmi of its sensor (see Figure 4-1). ATARS parameters undergo an expansion past the range of 50 nmi. These expansions should therefore never be experienced in this deployment. However, in this analysis, ATARS messages are computed in the program DUA assuming a single sensor at the origin. There are many aircraft in LAX-1840 at ranges greater than 50 nmi from the origin. For those aircraft, program DUA would expand the parameters, thus increasing the number of ATARS messages erroneously. Changing the value of the parameter RDIST to 100 nmi prevents this from happening since all aircraft in the LAX-1840 model lie within 100 nmi of the origin.

The total uplink activity on the channel must also account for surveillance. If there is at least one COMM-A to be delivered to an aircraft, then the surveillance function is automatically achieved and a separate surveillance interrogation is not necessary. Conversely, if a particular aircraft does not have even one COMM-A scheduled to be delivered to it, then a special surveillance interrogation must be scheduled solely to provide surveillance data. Message counting takes this into account.

The snapshot of aircraft positions provided in the LAX-1840 model can be thought of as the positions detected by the sensors from one complete scan of each sensor's antenna. (Radar errors are not modelled in this study.) The programs then essentially determine the actual data link messages that

would have been exchanged with each individual aircraft on that scan. The program BUNCH keeps track of these messages to individual aircraft. It also has the capability to provide various total counts for each azimuthal wedge in the scan for any specified azimuthal wedge size.

Section 5.2 presents an overview of DABS message rates in the LAX-1840. Section 5.3 presents peak loadings encountered in the analysis and presents azimuthal charts of data link and aircraft target loadings. Section 5.4 presents message rates from the point of view of a single aircraft. Histograms are presented for ATARS advisories and numbers of COMM-A messages to aircraft in the basin. Section 5.5 discusses the possibilities of reducing message rates with a modified ATARS proximity logic.

5.2 Message Rates in the 1995 Los Angeles Basin Model (LAX-1840)

Table 5-2 shows the data link loading for each of the eight sensors in the deployment scheme of Figure 4-1. It shows aircraft numbers and message counts for each sensor. A message is defined as a single uplink or downlink transmission. For example, a surveillance interrogation is counted as a message. Each COMM-C or COMM-D transmission is also counted as one message. Thus, a 12 segment uplink ELM accounts for 12 uplink messages (plus more for overhead). The eight sensors account for 1400 aircraft in the basin, an average of 175 aircraft per sensor. (The remaining 440 aircraft in the model are not covered by these eight sensors.) The actual target load per sensor varies from 47 to 381. About 80% of all targets are DABS-equipped. Total uplink message traffic for these eight sensors (including surveillance interrogations for those aircraft that do not receive a COMM-A) is 3202 messages or about three messages per DABS equipped aircraft on the average. 61% of these messages are due to ATARS and only 8% are due to uplink ELMs. The downlink data message volume for the eight sensors (excluding standard surveillance replies) is 266 messages per scan, most of it being made up of COMM-B messages. COMM-B messages provide downlink of airborne data and pilot requests or acknowledgments of various services.

Table 5-2 shows that the Burbank sensor is the most heavily loaded sensor, both in the number of targets being served and the total message volume. We see that it serves almost 400 aircraft per scan, about 300 of these being DABS-equipped. Such an aircraft load represents an average of about three aircraft per 2.4° beam dwell. It creates an average of about 200 uplink messages per second and about 20 downlink data

TABLE 5-2

MESSAGE RATES FOR LAX-1840

NUMBER	Sensor Name	Abbreviation	Number of Aircraft		Total Number of Messages In a Single Scan							
					Uplink					Downlink		
					COMM-A							
			Total	DABS Equipped	ATARS	Other	COMM-C	Surv	Total	COMM-B	COMM-D	Total
1	Norton AFB	NOR	240	181	229	112	65	57	463	36	10	46
2	Ontario	ONT	262	214	450	136	52	44	682	43	8	51
3	El Toro		151	122	93	73	26	41	233	30	4	34
4	Santa Ana	SNA	110	94	216	56	13	25	310	16	2	18
5	Long Beach	LGB	140	114	259	82	13	24	378	20	2	22
6	San Pedro		47	38	71	18	0	7	96	6	0	6
7	Los Angeles International	LAX	69	51	117	34	13	10	174	12	2	14
8	Burbank	BUR	381	305	529	199	65	73	866	65	10	75
	TOTAL		1400	1119	1964	710	247	281	3202	228	38	266

messages (i.e., 112 bit replies) per second.

DABS system designers, of course, need to know peak loads on a DABS sensor. Processing requirements are strongly determined by the peak target and data link requirements since the sensor works on the basis of a rotating beam and most of its tasks are performed in units of 11.25° azimuth sectors. Peak data link loadings also imply correspondingly higher interference with co-existing systems for the durations of those peaks. Table 5-3 presents peak loading numbers for LAX-1840 sensors. It shows target count peaks as well as message volume peaks. It may be remarked that the peak message rate for a sensor does not necessarily coincide with its peak target count, whether considering beam dwells or sectors. It is seen that the absolute worst peak beam dwell consists of a total of 12 aircraft (11 of them equipped) for the most heavily loaded sensor. For other sensors, the worst target peaks are about half as dense. Uplink message volumes in a beam dwell may be as high as 33. The densest sector contains 38 aircraft, 29 of them being equipped. For all other sensors the peak sector is no more than half as dense. A sector may experience up to 83 uplink messages. The total aircraft load on the Burbank sensor is 381 aircraft or an average of 2.5 aircraft per beam dwell. Thus, the peak beam dwell is about five times as dense as the average beam dwell as far as target density is concerned. Peak loading is quite important to system design and the next section is devoted to taking an even closer view of aircraft and message rate peaking in LAX-1840.

5.3 Peaking Phenomena

The two most basic units of computation for the DABS sensor are the beam dwell (2.4°) and the sector (11.25°). Aircraft interrogation scheduling takes place in beam dwell units. All major ATARS computations are carried out in sector units. This section contains azimuthal plots showing distributions of aircraft and data link messages over a scan. The analysis is presented for the most heavily loaded sensor, Burbank.

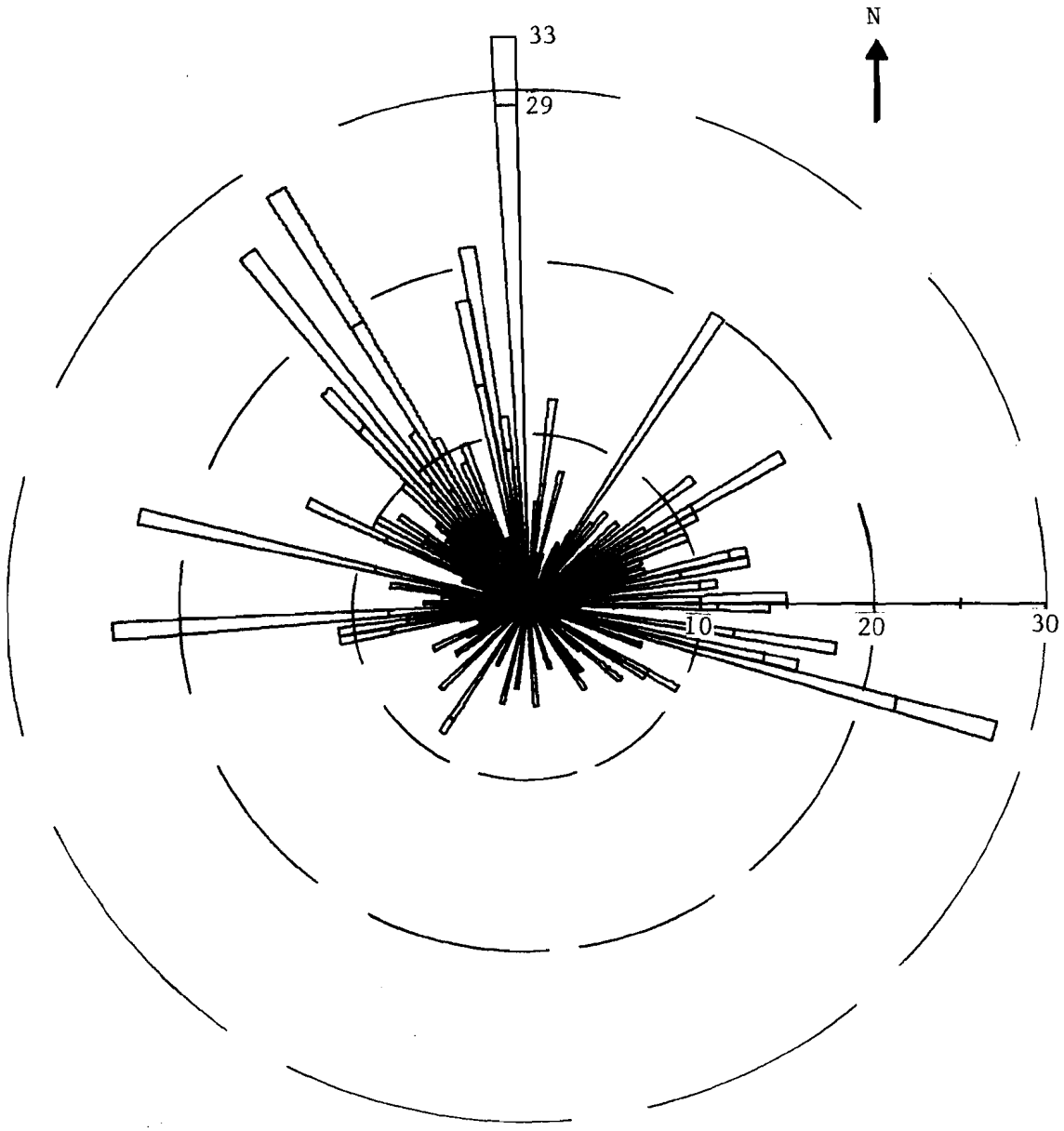
Figure 5-2 shows the distribution of uplink messages over each successive beam dwell for the entire scan. The radial length of each wedge shows the total number of uplink messages in that beam dwell. The portion contributed by ATARS is depicted by a division within each wedge. ATARS messages equal the distance from the origin to the dividing line. The Burbank sensor is seen to be required to send up to 33 uplink messages in one beam dwell. 29 of these are required by ATARS alone. It should be noted that the beam dwells immediately preceeding or

TABLE 5-3

PEAK LOADING CONDITIONS FOR LAX-1840 SENSORS

NUMBER	SENSOR NAME	PEAK BEAM DWELL (2.4°)				PEAK SECTOR (11.25°)			
		NUMBER OF AIRCRAFT		NUMBER OF UPLINK MESSAGES	NUMBER OF DOWNLINK MESSAGES	NUMBER OF AIRCRAFT		NUMBER OF UPLINK MESSAGES	NUMBER OF DOWNLINK MESSAGES
		TOTAL	EQUIPPED			TOTAL	EQUIPPED		
1	NORTON	6	5	30	5	19	14	43	5
2	ONTARIO	7	6	23	4	19	17	68	8
3	EL TORO	6	5	16	2	15	13	27	5
4	SANTA ANA	5	4	25	2	10	9	38	5
5	LONG BEACH	4	4	24	4	14	11	43	5
6	SAN PEDRO	3	3	15	1	5	5	21	2
7	LOS ANGELES INTERNATIONAL	4	2	16	3	8	5	15	3
8	BURBANK	12	11	33(1)	4	38	29	83(2)	6

NOTES: (1): 97% of these 33 messages are COMM-As
(2): 80% of these 83 messages are COMM-As



Total Uplink Messages = 866

Maximum In Any Beam = 33

Average In A Beam = 5.8

ATARS Contribution Is Indicated By The Distance From The Origin To The First Division Within Each Wedge

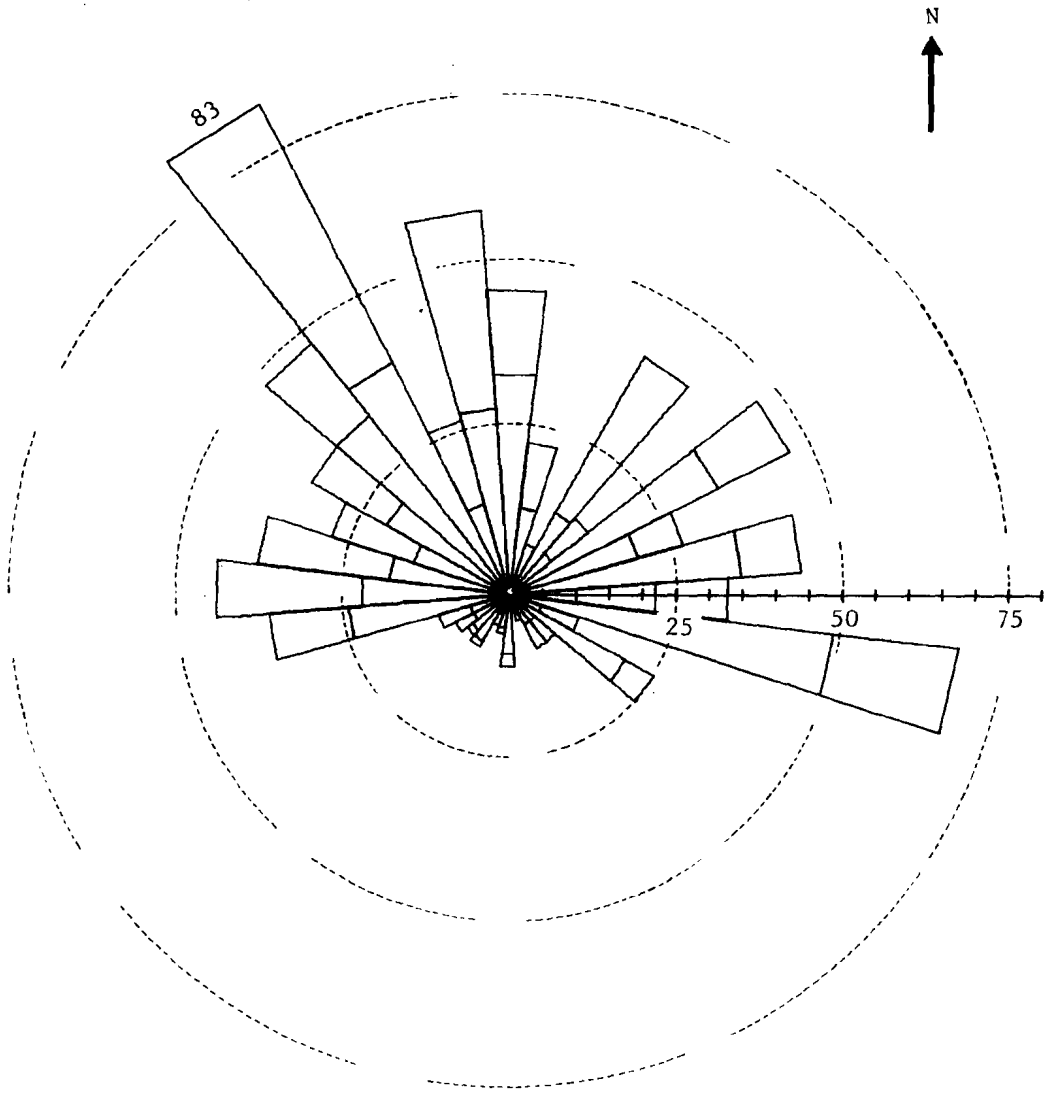
FIGURE 5-2
UPLINK MESSAGES BY BEAM DWELLS FOR A DABS SENSOR AT BURBANK IN LAX-1840 (NOMINAL ATARS OF REFERENCE 8)

following this peak beam dwell are both very sparsely loaded. Several other peaks are seen to contain more than 20 uplink messages, again always bracketed by beam dwells of considerably lower loading. The average number of uplink messages in a beam is 866/150 = 5.8.

Figure 5-3 shows uplink message distribution for the Burbank sensor by 11.25° sectors. It is seen that about 45 messages in a sector are quite common, although as many as 83 are found in the most loaded sector. 39 of these 83 are contributed by ATARS. The average load per sector is 27 uplink messages. An important observation from Figures 5-2 and 5-3 is that data link loading varies significantly within a scan and that peak loads are not usually sustained over long intervals.

Figure 5-4 shows the distribution of number of aircraft over successive beam dwells in a scan. The figure shows a peak of 12 aircraft flanked by beams with six aircraft each. The number of DABS-equipped aircraft is represented by the subdivision within each wedge, being equal to the distance from the origin to the dividing line in each wedge. 11 of the 12 aircraft in the peak beam dwell are seen to be DABS-equipped. Figure 5-5 shows the distribution of aircraft over successive 11.25° sectors for the Burbank sensor. As many as 38 aircraft may be visible to the sensor in one sector, 29 of these being DABS-equipped. The scan average for aircraft per sector is 12. 10 of these may be expected to be DABS-equipped. Figures 5-4 and 5-5 show that aircraft loads vary considerably over the scan and peak target loads are not maintained over successive beam dwells or sectors.

A comparison of Figures 5-3 and 5-5 shows a strong correlation between the number of aircraft targets and the number of uplink messages in a sector. If a sector contains a large number of aircraft, it also shows a heavy uplink message load. Such clear correspondence is not seen for beam dwell loadings (see Figures 5-2 and 5-4). This can be understood in the following way. ATARS contributes the largest portion of uplink messages. ATARS messages are determined by neighboring traffic densities. The minimum PWI range is two miles. At 20 nmi, a two mile circle subtends an 11.3° angle at the center. Thus, the 2.4° beam dwell is too narrow to account for all the aircraft detected and declared as proximate and threat targets by ATARS. However, when considered in 11.25° sectors, the data link message volume does depend upon the traffic density. Thus ATARS processing loads are correlated with aircraft densities in sectors.



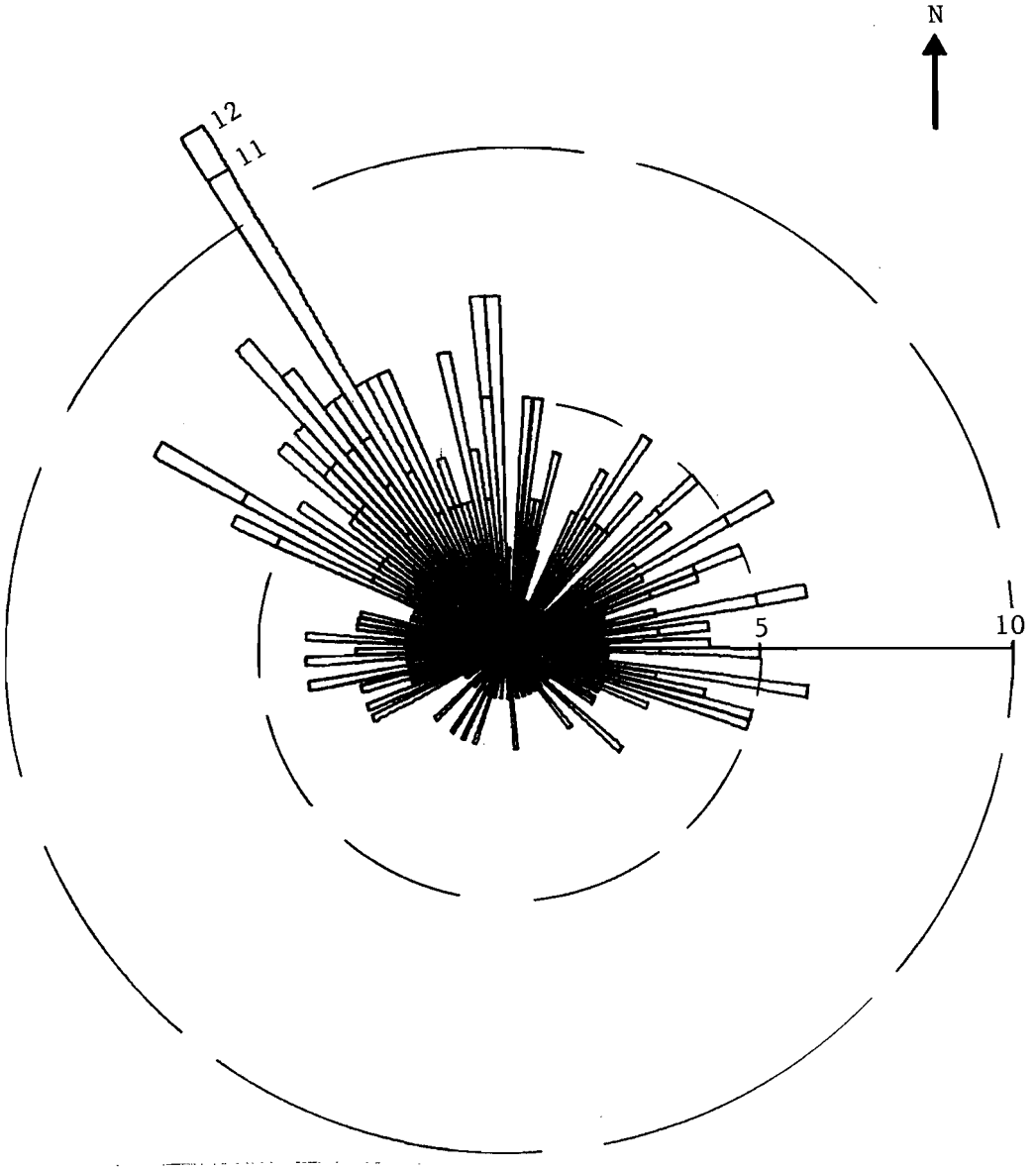
Total Uplink Messages = 866

Maximum In Any Sector = 83

Average In A Sector = 27

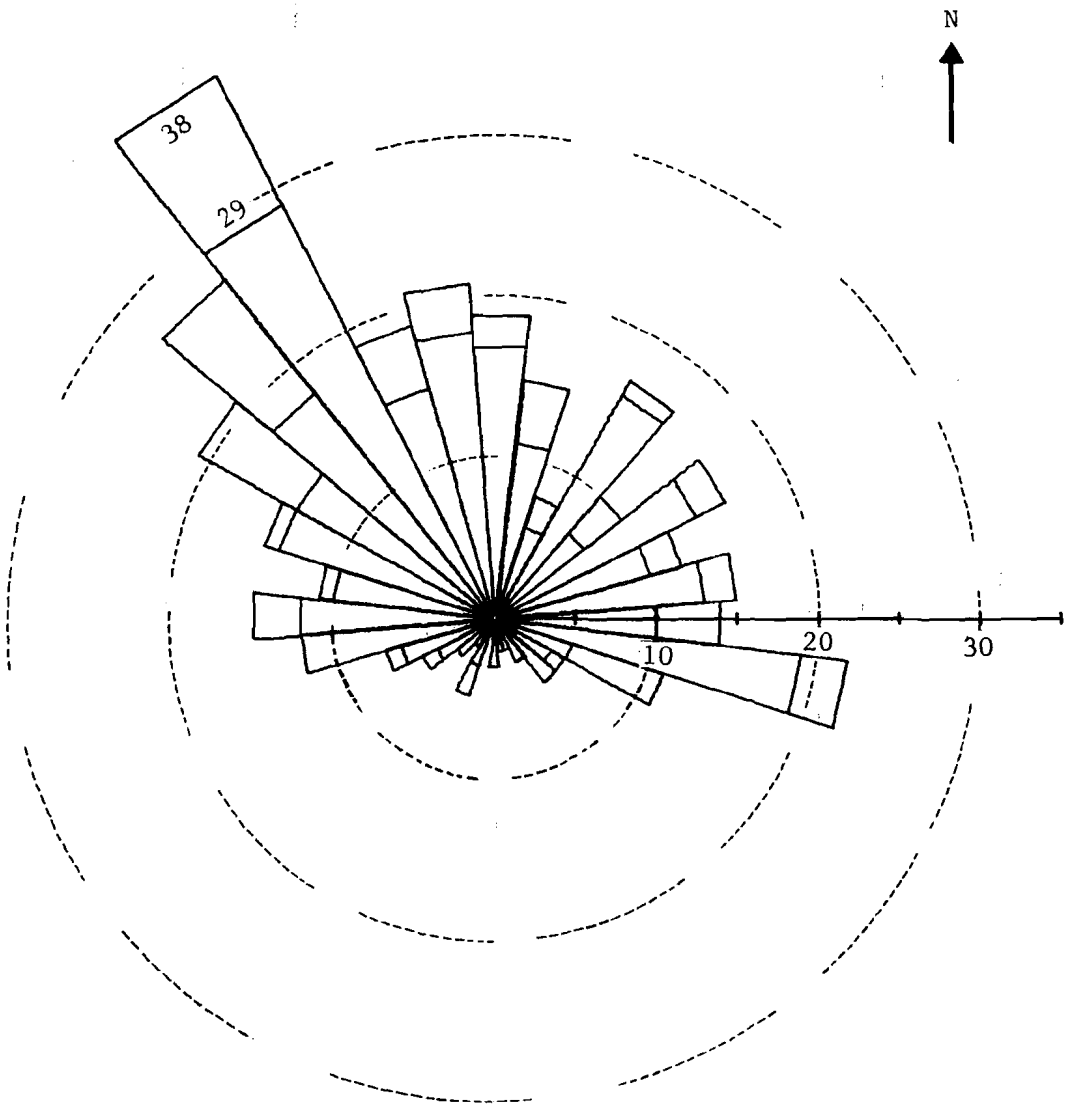
ATARS Contribution Is Indicated By The Distance From The Origin To The First Division Within Each Wedge

FIGURE 5-3
UPLINK MESSAGES PER SECTOR FOR DABS SENSOR AT BURBANK IN LAX-1840 (NOMINAL ATARS OF REFERENCE 8)



Distance From Origin To
The First Division Within
Each Wedge Represents
DABS Equipped Targets

FIGURE 5-4
DISTRIBUTION OF AIRCRAFT OVER SUCCESSIVE BEAM DWELLS FOR A SENSOR AT BURBANK IN LAX-1840



Distance From The Origin To
The First Division Within
Each Wedge Represents DABS
Equipped Targets

FIGURE 5-5
AIRCRAFT IN SUCCESSIVE 11.25° SECTORS FOR A SENSOR AT BURBANK IN LAX-1840

5.4 Messages to a Single Aircraft

Figure 5-6 shows a histogram of the number of COMM-A messages to be issued to each equipped aircraft in the LAX-1840 basin. It is seen that up to 15 COMM-As may be required to be delivered to an aircraft. (This happens to be one aircraft in the entire population.) Otherwise, it is seen that 98.4% of the aircraft receive up to eight COMM-As or less. More than half of the equipped aircraft receive none or only one COMM-A. It should be pointed out that this study assumes a 100% round reliability; that is, that each interrogation made by the sensor is assumed to be successfully received by the transponder. In practice, the reinterrogation rate may be expected to increase the probability of multiple COMM-A delivery slightly.

5.5 ATARS Advisories

The single largest source of COMM-A messages is ATARS advisories. The ATARS design formats provide for a maximum of eight advisories per target. Thus, if a target is detected to have more than eight ATARS advisories it will still receive only eight advisories. Figure 5-6 shows the frequency of ATARS advisories in the LAX-1840 model. Figure 5-7 contains three separate Figures, called 5-7-(a), 5-7-(b) and 5-7-(c) respectively. Figure 5-7-(a) is a histogram of the number of proximities for aircraft in the LAX-1840 model. Figure 5-7-(b) provides a histogram of the number of threat advisories to aircraft in that model. Figure 5-7-(c) shows a histogram of the total number of advisories (proximities and threats) to aircraft in the LAX-1840 model. It is seen that more than half the population receives no ATARS advisories (Figure 5-7-(c)). As many as eight advisories, however are issued for 3% of the population. Only about 20% of the aircraft receive threat advisories (Figure 5-4-(b)). Up to six threat advisories are seen to be issued for 0.07% of the population, which is one aircraft among the 1400 aircraft covered. In fact, it is this same aircraft with six threat advisories that receives a total of 15 COMM-As.

It is felt that such message rates are excessive. If traffic densities should, in fact, reach such high levels as assumed in the LAX-1840 model of Reference 15, an automated system deployed to point out traffic of potential concern would presumably be desensitized so as to present fewer targets. An excessive number of targets presented will only defeat the purpose of an advisory system. Therefore, an example of a less

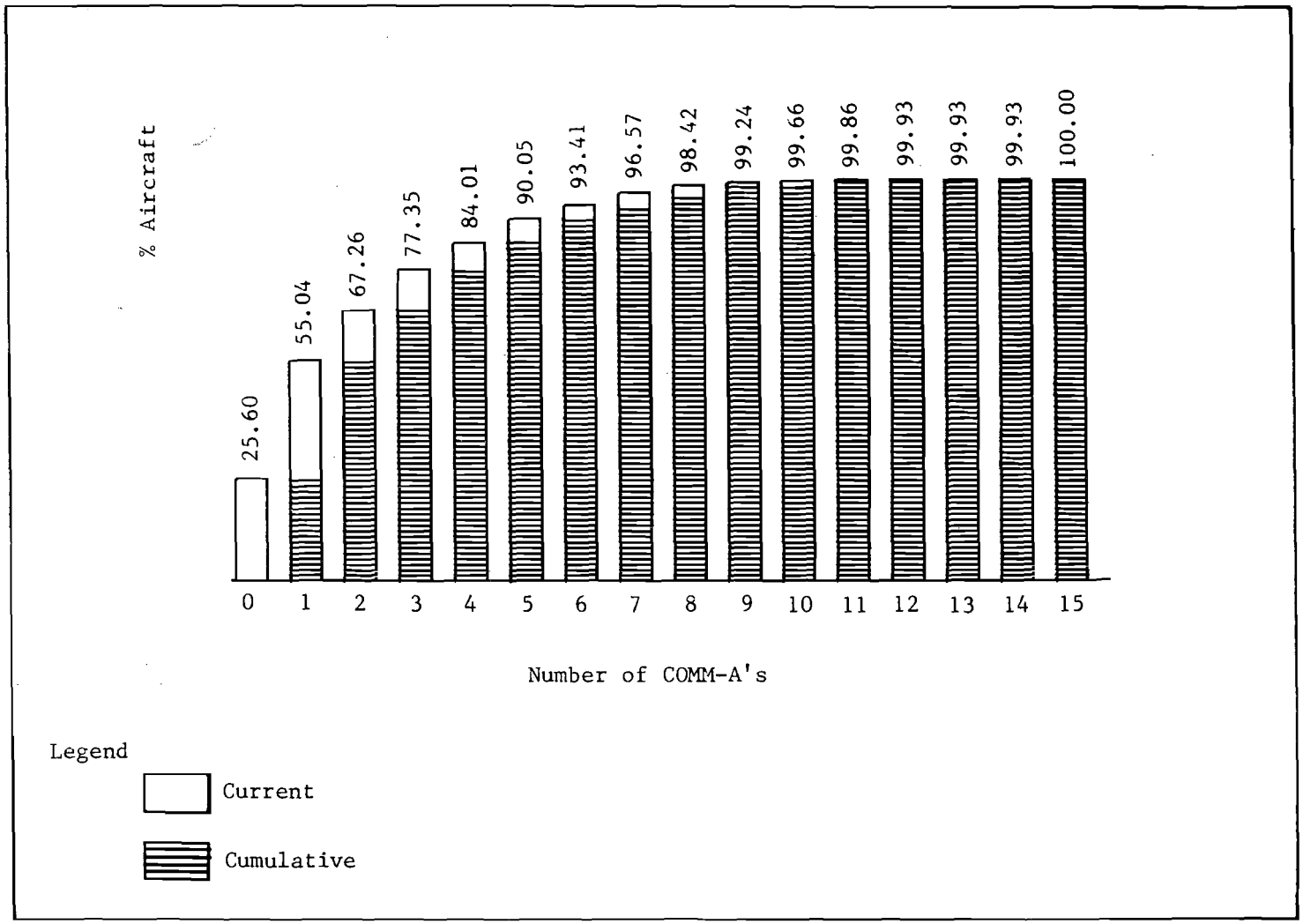


FIGURE 5-6
COMM-A MESSAGES TO EQUIPPED AIRCRAFT IN LAX-1840

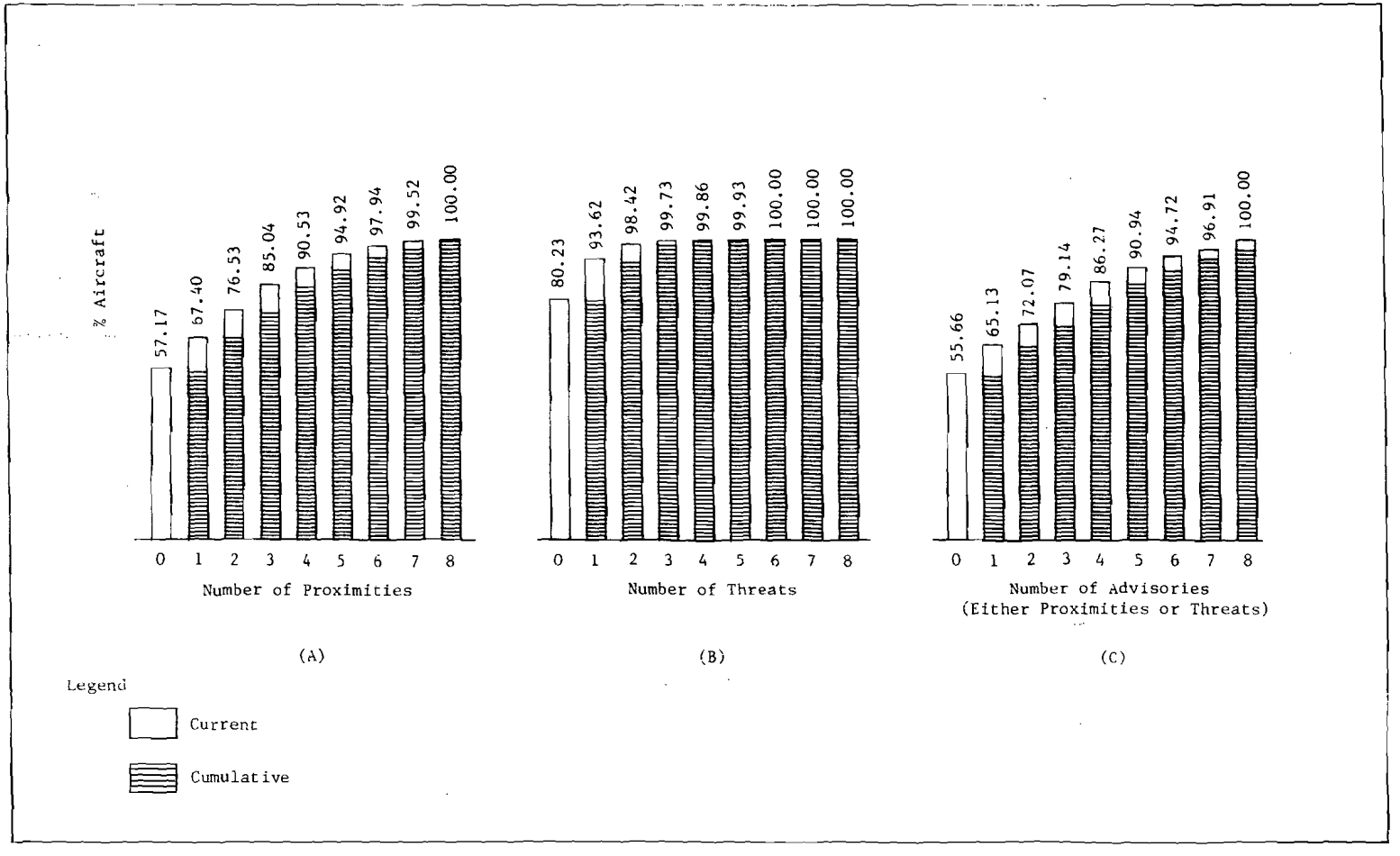


FIGURE 5-7
ATARS ADVISORIES TO EQUIPPED AIRCRAFT IN LAX-1840

sensitive ATARS that may be deployed in future dense traffic conditions was hypothesized. This hypothetical ATARS and the resulting advisory message rates are discussed in the next section.

5.6 Reduced Proximity Detection Logic

The ATARS algorithms (Reference 8) declare a proximity advisory when an intruder is within 2,000 feet in altitude from the subject aircraft and the horizontal proximity criteria are satisfied. The primary intent of ATARS proximities is to have available on the subject aircraft's display an indication of all aircraft that it could collide with in 30 seconds if it were to suddenly initiate a maneuver. The proximities cannot really be used to provide protection against an intruder initiating an abrupt maneuver. In order for the proximity advisory to protect against abrupt maneuvers by intruders, the pilot would have to continuously monitor his display to an extent which would be impractical. From this standpoint, the vertical proximity criterion could conceivably be dependent upon the subject aircraft's maneuvering capability. In the current ATARS algorithms the vertical proximity criterion is independent of the maneuvering capabilities of the subject aircraft.

In this study a new speed dependent PWI logic is devised as follows. Aircraft are classified in one of four speed classes. Each speed class has its own vertical protection parameter as shown in Table 5-4. Thus, for an aircraft under 120 knots the vertical detection parameter is 900 feet. The table also shows the maximum vertical rate for each speed class such that a pilot would have at least 30 seconds warning if he did not exceed that vertical rate.

Such a scheme, which uses parameters as functions of subject aircraft speed, necessarily creates an assymetry between proximity displays for two neighboring aircraft. Thus, aircraft A may get a proximity advisory on aircraft B while aircraft B, under certain conditions, may not receive a proximity on aircraft A. With such reductions in the proximity parameters, some intruders with vertical rates may also be detected as threats before they are detected as proximities. Such occurrences in fact already exist in the current logic for certain horizontal geometries and are not considered to be a problem.

The immediate altitude warning threshold for threats in Reference 8 is currently 1000 feet. Since the lowest

TABLE 5-4

SPEED CLASS SENSITIVE ALTITUDE THRESHOLDS
FOR A SPEED DEPENDENT PMI LOGIC

SPEED	120 knots	120 - 170 knots	170 - 250 knots	250 knots
VERTICAL PROTECTION PARAMETER	< 900 ft	1200 ft	1700 ft	2000 ft
MAXIMUM VERTICAL RATE FOR 30 SECOND WARNING	1800 ft/min	2400 ft/min	3400 ft/min	4000 ft/min

corresponding proximity detection parameter is 900 feet, the threat parameters (AFPWI and AFIFR) were reduced to 750 feet for the reduced logic.

The changes indicated above were all easily incorporated within the "PWI-ACCUMULATOR" module of the ATARS programs used for this analysis. No changes to the "DETECT" module were necessary (see Reference 8).

Figure 5-8 shows histograms of ATARS advisories to aircraft in the LAX-1840 model for this reduced ATARS logic. This figure should be compared to Figure 5-7. Some improvement can be detected in the large number of ATARS advisories with the change in logic, although the change is certainly not dramatic. Figure 5-9 shows a histogram of COMM-As delivered to equipped aircraft in the basin with this logic. This figure should be compared to Figure 5-6. It can be seen that for situations involving four or more COMM-As the reduced logic issues about one COMM-A less than the nominal logic. Thus, while the nominal logic issues up to eight COMM-As to 98% of the aircraft, the reduced logic issues up to seven COMM-As to 98% of the aircraft. Table 5-5 summarizes the comparisons between the outputs of the two logics. It can be seen that the speed dependent PWI logic provides about a 20% reduction in ATARS advisories and uplink messages. This is not considered to be a major reduction.

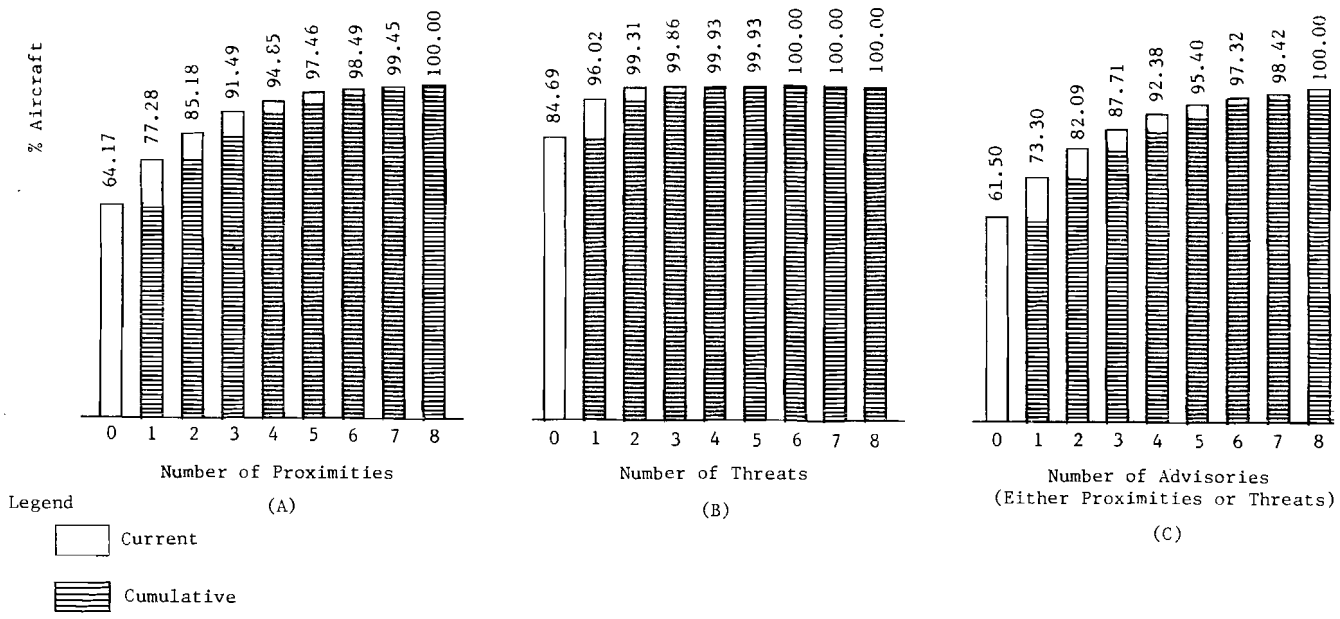


FIGURE 5-8
ATARS ADVISORIES TO EQUIPPED AIRCRAFT IN LAX-1840
FOR A SPEED DEPENDENT (REDUCED) PWI LOGIC

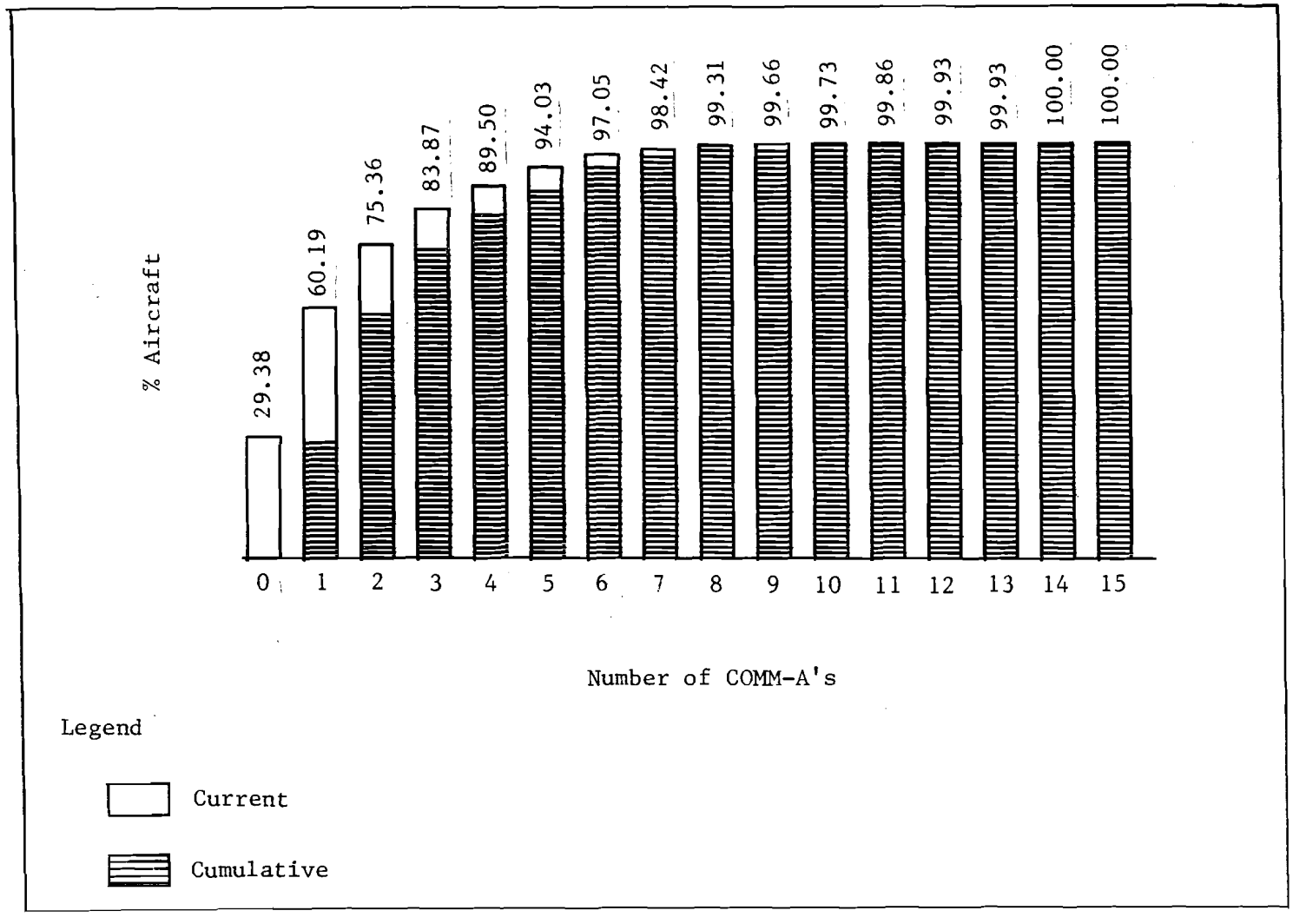


FIGURE 5-9
COMM-A MESSAGES TO EQUIPPED AIRCRAFT IN LAX-1840 WITH A SPEED DEPENDENT (REDUCED) PWI LOGIC

TABLE 5-5

COMPARISON OF MESSAGE RATES FOR NOMINAL AND SPEED DEPENDENT PWI LOGICS

		Results Using Nominal ATARS	Results Using Speed Class Dependent Threshold For Proximities	Comments
Average Number of ATARS Advisories Per Aircraft (Proximities & Threats)	Mean Standard Deviation	1.6 2.3	1.1 1.9	30% Reduction 17% Reduction
Average Number of COMM-A's Per Aircraft (For Entire Basin)	Mean Standard Deviation	2.1 2.3	1.7 1.9	19% Reduction 17% Reduction
Uplink Messages	Total For Basin	3755	3249	Nearly 18% Reduction
	In Average Beam In Ontario	4.6	3.7	
	In Worst Beam In Burbank	33	27	

6. SUMMARY, DISCUSSION AND RECOMMENDATIONS

This section summarizes the results of this report. It then discusses specific assumptions made in the analysis that affect the results significantly. Finally, recommendations for further work are provided.

6.1 Summary of Results

This report presents an analysis of the data link implications of deploying the DABS system to provide projected services in the 1995 time frame to the most demanding air traffic environment in the U.S. This environment is represented by an air traffic model of the L. A. Basin in 1995, and consists of 1840 aircraft in an area approximately 60 nmi in radius. The region is assumed to be served by eight sensors. A variety of services that can reasonably be expected to be available by 1995 are assumed to be provided. ATARS algorithms used are taken from Reference 8. Multi-site and failed sensor considerations have not been taken into account. 100% link reliability has been assumed. Data link formats presented in References 8 and 11 have been used. With these assumptions, it is found that in order to deliver all projected services to aircraft each scan (i.e., without a queuing delay) the DABS sensor must be capable of meeting the following requirements:

1. The sensor should be capable of providing surveillance and data link services to 400 aircraft. It should be capable of handling peaks of up to 38 aircraft in an 11.25° sector and up to 12 aircraft in a 2.4° beam dwell (Tables 5-2 and 5-3).

2. The sensor should be able to deliver uplink COMM-As, downlink COMM-Bs, and uplink ELM messages.

3. The DABS sensor should be able to deliver up to 15 COMM-As to an aircraft (Figure 5-6).

   NOTE: If the sensor can only deliver eight COMM-As then, about 1.6% of the population will not receive some of its messages on a given scan. With proper message delivery protocols and favorable conditions these aircraft may be able to receive those messages on a later scan.

4. The DABS sensor should be able to deliver up to 866 uplink messages in one scan, 84% of these being COMM-As. It should be able to transact 75 downlink data messages each scan, 87% of these being COMM-B messages (Table 5-2).

5. The sensor should be able to deliver up to 83 uplink messages in an 11.25° sector, 80% of these being COMM-As, and up to 33 uplink messages in a 2.4° beam dwell, 97% of them being COMM-A's (Table 5-3).

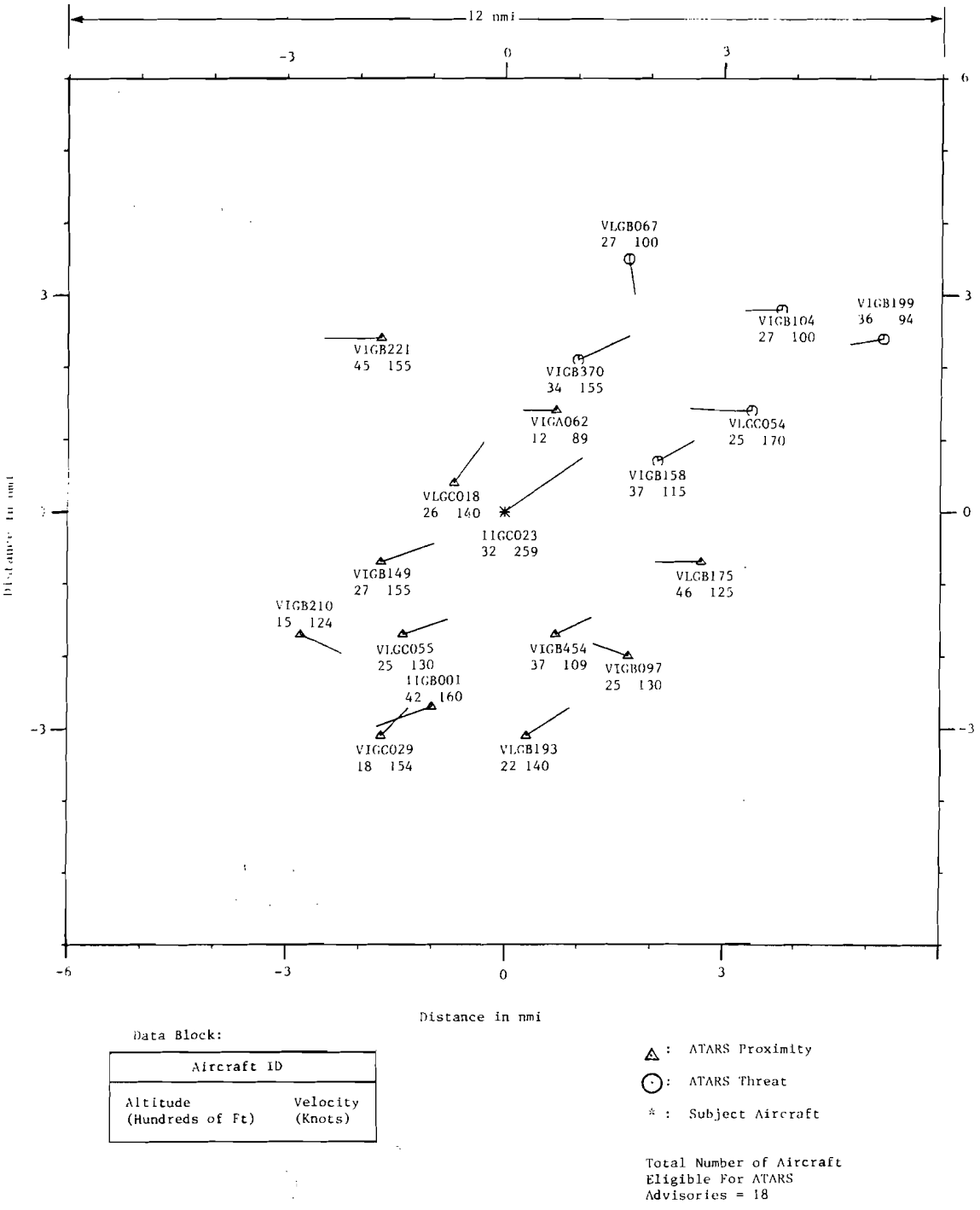
The major contributor to the data link activity is ATARS, which accounts for 61% of the uplink message traffic. Use of a speed dependent altitude threshold logic for proximities does not significantly reduce ATARS advisories.

Establishing the message volume for one scan of the DABS antenna and peak message volumes in shorter asimuthal wedges was the chief goal of this study. This has been accomplished and is reported in items (4) and (5) above. As will be discussed in the next section, these message volumes represent upper limits to the messages that may be expected from a DABS sensor in the worst traffic environment in the 1995 time frame. Besides these results, probably the most significant requirement indicated by this study is the need for multiple COMM-As to single aircraft. Item (3) above indicates that 98.4% of the DABS equipped targets in the sensor's jurisdiction require up to eight messages per scan in the 1995 air traffic environment. Reference 16 provides for up to three interrogations to a single aircraft. Figure 5-6 shows that nearly 25% of the DABS equipped population requires more than three COMM-A messages each scan. As a result of this finding, the currently proposed Engineering Requirements specifications for the procurement of DABS sensors (Reference 17) include a requirement for 10% of the targets in the population to be interrogated up to eight times. The exact requirements on DABS capacity in this regard are the subject of a revised study to be reported in Reference 1. Such a revision to the present study is necessary due to known limitations of this analysis. This is the subject of the next section.

6.2 Discussion of Limitations of the Present Study

a. LAX-1840 Model. The model of Reference 15 was created in 1972 with FAA aviation forecasts available at that time. Aviation forecasts have since experienced a significant downward trend due to the energy crisis. It is believed that the LAX-1840 model used here contains densities considerably higher than those that would be obtained with current forecasts.

The densities experienced in this model are very high and are exemplified by a cluster of 19 aircraft shown in Figure 6-1. A two row data block is associated with each aircraft.



Data Block:

Aircraft ID	
Altitude (Hundreds of Ft)	Velocity (Knots)

△ : ATARS Proximity

⊙ : ATARS Threat

* : Subject Aircraft

Total Number of Aircraft Eligible For ATARS Advisories = 18

FIGURE 6-1
A DENSE AIRCRAFT CLUSTER IN LAX-1840

The first row contains a seven character ID (e.g., IIGC023). The first number in the second row of the data block identifies the aircraft altitude in hundreds of feet and the second number represents the aircraft speed in knots. The aircraft velocity vector is represented by a line drawn from the present position in the direction of its travel. The length of this line is proportional to the speed of the aircraft. The aircraft of interest, IIGC023, is shown at the center by an asterisk. Every aircraft that generates an ATARS advisory for it is shown in Figure 6-1. Threats are represented by circles and proximities by triangles. It is seen that ATARS detects a total of 18 advisories (six threats and 12 proximities) for the subject aircraft.

Figure 6-1 only depicts ATARS advisories to the subject aircraft (IIGC023). Actually, there are many more aircraft in the neighborhood of our subject aircraft. For example, there are a total of 69 aircraft within six nmi of the subject aircraft, 54 of these being within 2000 feet in altitude of the subject aircraft. The 18 aircraft shown in this figure are a subset of these 54 aircraft. The remaining aircraft are filtered out by the ATARS algorithms.

b. Sensor Deployment. The sensor deloyment scheme assumed in this study gives little consideration to optimization of the coverage of airspace. The eight sensor locations do include the five ARTS-III Sites currently existing in the L. A. Basin. The other three sites, however, are chosen somewhat arbitrarily and without regard to topography or optimum airspace coverage. One result of this is a highly inequitable distribution of sensor loadings. Table 5-1 reveals these discrepancies. It was seen there that the Burbank sensor needs to handle almost 400 aircraft whereas the San Pedro sensor needs to serve only about 50 aircraft.

c. Multi-Sensor and Failed Sensor Considerations: ATARS multi-site coordination and failed sensor considerations are not included in this analysis. Both require coverage of additional airspace by each sensor involved. Thus, if included, they would imply increased target and message rate loadings on individual sensors.

d. Services: This analysis does not include a separate CDTI service that may issue large amounts of information to subject aircraft on numerous surrounding targets above and beyond that provided by ATARS. The utility of presenting large amounts of information on numerous surrounding targets has not been demonstrated. If such need should

become established then the total and peak uplink message rates would be more than those presented here.

In general, predicting future services is a difficult matter. The set of services included in this study, however, represent a set that is quite reasonably achievable.

e. Data Link Service Formats: This study assumes that ATARS commands are delivered in single COMM-A threat messages. Some formats now being proposed (Reference 18) indicate that multiple COMM-A messages may be required for ATARS/BCAS coordination. Such formats will not significantly impact total link utilizations. However, they will impact COMM-A delivery requirements for single aircraft. Other ATARS formats being revised (e.g., threat advisory formats, Reference 18) will reduce data link requirements.

Of all these factors that may affect the results of the analysis presented in this study, item (a) (traffic model) is expected to have the most significant impact. Since the LAX-1840 model is too dense, the data link rates obtained in this analysis are correspondingly high. Data link rates presented here are therefore, expected to be upper bounds.

6.3 Recommendations

The data link requirements indicated in this analysis are very likely greater than those that would be obtained with a more realistic traffic model. Designing a sensor to meet requirements greater than actually necessary has cost implications. It is therefore recommended that the LAX-1840 model be revised using current forecasts and that this revised traffic model be used to establish DABS data link requirements for production DABS sensors.

The radio frequency activity numbers obtained in this analysis are also expected to be higher bounds. It is recommended that these numbers be used for an initial estimate of DABS/ATCRBS interference. If the level of interference created by DABS for ATCRBS is found to be acceptable even at these higher bound levels one can be sure that the actual interference levels will be acceptable. In that case, there will be no need for obtaining revised estimates of DABS radio frequency activity for the purposes of estimating DABS/ATCRBS interference.

APPENDIX A

COCKPIT DISPLAY OF TRAFFIC INFORMATION (CDTI)

This study does not include the use of a separate CDTI service in estimating the data link loading requirements on DABS. This Appendix explains the justification for this approach.

Table A-1 lists nine potential roles for the CDTI function as identified in Reference 19. Table A-2, excerpted from Reference 20, also shows a similar list and is consistent with the former. Table A-1 identifies the requirements for each CDTI function in terms of the number of targets to be displayed and their required resolutions. Most CDTI functions require the display of one or two proximate targets and one function requires the display of up to six targets. Runway occupancy monitoring, however, may require a display of up to 12 targets. Reference 19 does not establish the number of targets for the general traffic monitoring role for lack of sufficient data. A nominal value of six has been suggested there, with a maximum of up to 20 targets, both numbers being subject to revision by future studies. Research is currently underway towards an understanding of this CDTI role (amongst others). Reference 21 indicates that airline pilots prefer to be presented with no more than three or four targets on a display designed for traffic monitoring. The general terminal area traffic monitoring role may then be estimated to require a display of three or four targets. Thus, each of the CDTI roles identified in Table A-1, except for runway occupancy monitoring, requires a display of no more than six proximal targets.

ATARS provides for the uplinking of data on eight targets each scan. ATARS protection volumes are large enough that the proximal targets required for the CDTI roles may often be expected to be a subset of the proximities declared and uplinked by ATARS. ATARS uses 1200 ft resolution for its data which is approximately the resolution requirement of CDTI roles (except for runway occupancy monitoring).

CDTI functions usually require the uplinking of aircraft IDs and perhaps fixed geographical maps. Intruder aircraft IDs only need to be uplinked once during the life time of an encounter, which may be several minutes. Similarly, geographical maps would need to be uplinked no more than once in a few minutes, depending upon aircraft speed. Update rates of once in a few minutes imply updating once in 40 or 50 scans. The resultant average loading per scan due to these is very small compared to other data being uplinked once every

TABLE A-1

POTENTIAL CDTI ROLES AND THEIR DATA REQUIREMENTS[1]

Potential CDTI Function	Maximum Number of Targets to be Displayed	Required Horizontal Resolution[2]
A. Traffic Monitoring Roles		
1. General Terminal Area Operations (General Traffic Monitoring)	Not Known[3]	About 1000 ft
2. Longitudinal Separation of Arrivals	1	1000 ft
3. Independent Parallel Approaches	2	4 Milliradians (azimuth)
4. Runway Occupancy Monitoring	12	25 ft. No Altitude Necessary
B. Air Traffic Control Roles		
5. Arrival Merging	2	1000 ft
6. Arrival In-Trail Spacing	3 (max)	(Not Specified)[4]
7. Departure Separation	1	1000 ft
8. En-Route Passing and Crossing	1	3000 ft
9. Aircraft Separation During Severe Weather	6 (max)	1000 ft

1. Source: Reference 19.
2. Unless otherwise specified, altitude in 100 ft increments is necessary.
3. Reference 19 recommends further testing in order to fix this number. Reference 21 indicates 3 or 4.
4. Function of required spacing. About 900 ft for 3 nmi spacing.

TABLE A-2

POTENTIAL CDTI FUNCTIONS AND SOME POSSIBLE LIABILITIES

(Excerpted from Reference 20; Dr. Koenke's testimony)

Some potential CDTI functions are:
o Situational Awareness o Detection of Loss of Separation o Parallel Approach Monitoring o Runway Occupancy Monitoring o Pilot Controlled Spacing o Pilot Controlled Merging o Weather Avoidance o Navigation o CAS Display
Associated with these potential roles and their obvious benefits are some not so obvious potential liabilities. Among these are:
o Crew Workload o Inappropriate/Unjustified Pilot Reaction o Interaction with a CAS o Flow Stability and the Effect on Airport Capacity o Controller Workload

scan. In summary, except for runway occupancy monitoring, the data link loading estimates provided by ATARS are expected to cover for the possibilities of CDTI functions being provided in the cockpit.

Runway occupancy monitoring requires the display of more than eight targets, most of them being on the airport surface. The modeling of such a service is not possible in this study since the traffic model employed does not include vehicles on the airport surface. Besides, DABS can only provide this service if there is an effective ground surveillance system that can be properly integrated with DABS. However, a short discussion is now provided in order to understand its possible impact on data link loading, assuming such a service could be provided via DABS.

This service requires 25 ft resolution for positional data. 11 data bits at this resolution imply a range of eight nmi. 22 bits provide horizontal information on one target. No altitude information is required for this service. Thus, information on two targets can be uplinked in one COMM-A. 12 targets would require six COMM-As. The aircraft receiving this service are those on final approach, nearing the runway. Therefore, they are expected to be at low altitudes. Due to limitations imposed by the floor of coverage map, a DABS sensor may not be able to provide this service at many other airports besides the airport of its location. Thus, only a few aircraft (those on final approach at one or two airports) in the total population of about 400 targets are eligible to receive this CDTI service. The additional load created by this service is therefore not expected to be significant.

In summary, CDTI functions involve the display of positional data on a few proximate targets. Although these functions are not presently known in sufficient detail to facilitate their modeling in this study, many of the proximal targets to be displayed for the CDTI functions are expected to be a subset of ATARS proximities. Data resolution (accuracy) requirements are also comparable for CDTI and ATARS. Thus, as far as data link loading is concerned, ATARS is expected to account for most of the loading requirements that might be placed by CDTI functions. Some of the CDTI functions may, however, imply a small additional load on the data link beyond that accounted for in this study.

APPENDIX B

AVIONICS EQUIPAGE

This appendix provides the scheme to re-classify aircraft in the LAX 1840 model (Reference 15) so that classification in that model becomes consistent with national fleet projections of the DABS Transition Plan (Reference 14).

B.1 DABS Transponder Equipage

According to the DABS Transition Plan, all but the low-performance (i.e., single engine) general aviation fleet becomes completely equipped with DABS transponders, whereas 71.9% of the single-engine fleet becomes DABS-equipped. From Table 4-1, this translates into 22.5% of the total population being unequipped.

The LAX-1840 model contains a total of 1840 aircraft. Thus, .225 x 1840 = 414 of these would be unequipped. All these would be single engine aircraft. There are a total of 1335 single engine aircraft in the model. Thus, 414/1335 = 31% of the single engine aircraft in the LAX-1840 model should be assigned "unequipped" status.

B.2 Downlink of Airborne Data

All but the single engine general aviation aircraft are assumed to be equipped with avionics for gathering airborne data (airspeed, heading, etc.) and providing it to the transponder. According to the Transition Plan, 20.3% of all aircraft fall into this category (classes A, B and C in Table 4-1). Thus, 373 out of the total of 1840 aircraft in LAX-1840 should be so equipped. Table B-1 provides an appropriate mapping by aircraft-type for such a classification.

B.3 ATC Services

ATC messages are issued to IFR aircraft and controlled VFR aircraft. The LAX-1840 model does not indicate controlled status (e.g., within the TCA) for VFR aircraft. The total percentage of aircraft receiving ATC services was therefore obtained from Reference 10. IFR and controlled VFR aircraft form 43.8% of the total aircraft population in the model used in Reference 10. Use of this percentage in the LAX-1840 model yields a total of 806 aircraft under ATC control. Of these, 278 are IFR aircraft. Thus 528 VFR aircraft in the LAX-1840 model are assumed to be controlled. A further breakdown of the IFR aircraft into arrivals, departures, withins and overs is done on the basis of information described in

TABLE B-1

SCHEME FOR ASSIGNING THE CAPABILITY
TO DOWNLINK AIRBORNE DATA

LAX-1840 Class of Aircraft	Total Number in LAX-1840 Model	% Assigned to Downlink Airborne Data	Number of Aircraft Eligible to Downlink Airborne Data
Air Carriers	128	100%	128
Non-Air-Carrier Turbine, Jet And Heavy Multi-Engines	116	100%	116
Light Multi-Engines (Less Than 12,500 lbs)	261	50%	129
TOTAL	---	---	373

Reference 15. This breakdown is shown in Table 3-8. Only the itinerant VFR aircraft are assumed to be controlled. Since there are a total of 759 VFR itinerant aircraft in the LAX-1840 model, 69% of these (i.e., 528 aircraft) are assigned controlled status for purposes of ATC message delivery. It may be noted that the controlled status of these VFR aircraft is not carried into the ATARS algorithms being executed on the model. ATARS gives a preferred treatment to "controlled" aircraft. Only the nearly 15% of the aircraft that exist as IFR aircraft in the LAX-1840 model are treated as these preferred "controlled" aircraft in the ATARS algorithms in this study.

APPENDIX C

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