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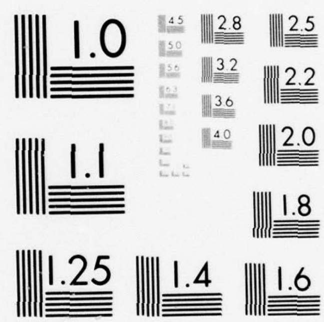

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functional utilization of DABS Data Link

Discrete Address Beacon System

October 1978

FINAL REPORT

DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Prepared by

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Prepared for

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16. Abstract

The report describes the output of a Task Force established by FAA Headquarters, SRDS, Robert Wedan, in June 1977 to study and recommend potential applications for Data Link to the DABS Experimentation Program.

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PREFACE

This document describes the results of a study undertaken June-July 1977 by a Task Force established by R. Wedan, Deputy Director, Systems Research and Development Service, FAA Headquarters. The Task Force was composed of personnel from The Transportation Systems Center and FAA Headquarters Systems Research and Development Service (SRDS), Air Traffic Service (AAT), Airways Facility Service (AAF), and Flight Standards Service (AFS). This document, a compilation of the Task Force effort, was written by J. Canniff and J. Golab of the Transportation Systems Center, and edited by R. Mahan of Raytheon Service Company.

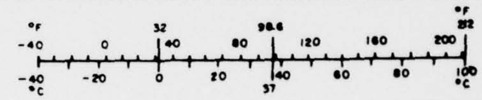
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

Approximate Conversions from Metric Measures

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



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1.0 INTRODUCTION

The "Functional Utilization of DABS Data Link" is a report on the results of a 1977 Task Force study effort to recommend potential operational applications of voiceless two-way digital communications between aircraft and FAA Ground Facilities to be tested for evaluation purposes in the DABS Experimentation Program. Data Link messages are transmitted (air-ground/ground-air) through Input/Output (I/O) equipment with messages originating from cockpit keyboards and FAA Ground Facilities.

Messages transmitted to aircraft are discrete, i.e., directed toward a specific aircraft, and using a particular assigned code as the means of address. Messages are received automatically through printers and/or video display units. In the foreseeable future some messages presently requiring manual input will be transmitted and received automatically through the use of computerized data, thus reducing substantially the controller/pilot workload.

The present Air Traffic Control Radar Beacon System, ATCRBS, has the capacity to identify on radar all DABS transponder equipped aircraft. The ATCRBS ground sensor scanner transmits a signal effecting a response not only from ATCRBS transponder aircraft, but also from those equipped with DABS transponders. This transponder response is then displayed on the radar unit viewed by the air traffic controller. It will be through this DABS transponder unit, by way of the DABS ground radar sensor scanner, that future data link messages will be transmitted and received.

At some future date it is expected that the DABS ground radar sensor scanner will replace the present ATCRBS ground system. However, the flexibility of DABS, and its compatibility with the present system, allows for a progressive, non-disruptive, efficient and economical replacement.

Thus, this document, "Functional Utilization of DABS Data Link", addresses itself only to the current DABS experiment program. The program, as described in this work, concerns itself with suitable areas for experiment and testing, priority of message types, interfacing of advancements with the present system, and types of software and equipment required. These areas of concern are few, and only partly cover the many facets of the complex program which is the "Functional Utilization of DABS Data Link".

2.0 OPERATIONAL REQUIREMENTS FOR DATA LINK

The operational need for some form of digital air-ground/ground-air data link has been addressed by a number of national and international organizations over a period of years, such as the Federal Aviation Administration (FAA), and the International Civil Aviation Organization (ICAO). In studies conducted it has not been possible to identify a specific point in time or a unique set of operational requirements where the present voice communication system will be inadequate and a data link supplement will be absolutely required. This is due, in part, to the expansibility of the present ATC system and the evolutionary nature of future systems. However, there is general agreement that a data link capability will be required in the foreseeable future. Some of the factors which contribute to this general consensus are discussed below.

Safety of Flight - The principal motivation in the implementation of data link is the increase in safety that will result. Time-critical messages will be delivered to the aircraft quickly and efficiently, with no loss of information from garble, thus increasing the likelihood that hazards to flight will be resolved before they become critical.

Understanding radio communications can be difficult, especially when both pilot and controller initiate messages at precisely the same moment, with the effect of cancelling each other out. Digitized data link messages, discretely directed, can circumvent such interference in contoller/pilot communications and assure transmission of time critical messages and further enhance safety of operations.

VHF Frequency Saturation - As the volume of air traffic increases in the future and more services are extended to the aircraft, there will be an increased demand on voice channel utilization. This is already evident in two ways: sectors within a given ATC facility have become smaller and more numerous, thereby creating a greater demand on the limited channels available; and the communication load within a sector will, in time, become higher to the point of saturating the channel. A data link capability would relieve such saturation.

Controller and Pilot Workload Benefits - A significant portion of a controller's workload is attributable to two-way voice communications. At times this task also becomes demanding to the pilot or a crew member of an aircraft. Thus the workload would be diminished if a portion of the air-ground/ground-air communications were transmitted over a data link.

Message Integrity - There are examples in two-way voice transmissions where messages become garbled to the extent of being unintelligible, or words and phrases are simply misunderstood. The integrity of radio transmissions by individuals, both controllers and pilots, varies considerably despite standard phraseology required in ATC. The clarity of voice transmission also varies according to the individual's ability to project his voice to obtain proper modulation; however, even with good radio technique, other factors such as poor voice quality and marginal equipment could effectively alter the quality of transmission. A data link capability where messages are displayed would improve significantly the integrity and verification of communications.

New and Improved Communication Services - The advent of digital technology, including a data link capability, allows for the high speed transmission of large volumes of data. This, of course, also allows the capability of providing services which were not attainable in the past, and of increasing the delivery speed of present services. Examples of new services involving large volumes of data include the uplink (ground to air) of digitized weather contours, navigation charts, and raw target reports for on-board separation assurance computations, as well as the downlink (air to ground) of raw flight data. These types of data increasingly are generated in digital form and lend themselves to transmission over a data link.

Speed of Message Transmission - The utilization of digital data link will decrease the required transmission time for all message types, critical and routine. Under future concepts such as ATARS, Automatic Traffic Advisory and Resolution Services, it will be possible to issue programmed commands directly to the aircraft, thus allowing more time to resolve conflicts.

TSC STUDY ON FUNCTIONAL UTILIZATION OF DABS DATA LINK

Study Initiation - In June 1977, the Transportation Systems Center (TSC) received a request from FAA Systems Research and Development Service, to prepare a plan for development of the functional utilization and hardware/software aspects of the DABS data link as it would be intefrated into the ground communication system. A Steering Group comprised of Division Chiefs from Systems Research and Development Service (SRDS), Office of Systems Engineering and Management (OSEM), NAFEC, FAA Air Traffic Service (AAT), FAA Airway Facilities Service (AAF), and Flight Standards Service (AFS) was set up to offer technical direction to the study. In response to this request TSC formed a study team with representation from each of the functional areas of interest to the study. Periodic reviews with the Steering Group were held as the study progressed. In addition, technical interfaces were established within the FAA to provide for information flow to the study team.

Study Objectives - The primary objective of the study is to identify requirements for a test bed for the DABS Engineering Model demonstration of data link applications for selected functions which will be established at the NAFEC facility in 1979; NAFEC will also serve for future tests as the data link functions become more inclusive. The applications would necessarily be related to on-going FAA programs. Secondary objectives of the study were to:

a) Demonstrate to the FAA, commercial and general aviation, and to airline operations, new safety and information service;

b) Prepare for possible early implementation of services that show substantial safety benefits; and

c) Provide a blueprint for ground communications needed to interface with the DABS data link.

The scope of the study was to encompass the interests of both general aviation and commercial aviation. Major functional areas to be considered were:

a) Control Message Automation;

b) Flight Service Station Automation; and

c) Airport Surface Traffic Control.

In addition, the study was to pay considerable attention to the possible use of a stand-alone data link facility using an omnidirectional DABS antenna that could be implemented earlier and at lower cost than the full DABS surveillance system. This feature would be of special interest to applications requiring airport surface coverage. The approach adopted by the study team in determining the candidate systems is outlined below:

- Document FAA technical program plans.
- Document DABS test facility plans, schedules and capabilities.
- Document technical requirements associated with each functional area consistent with FAA program plans and user group constraints. Consider various levels of automation.
- Define candidate functional areas and consider possible methods of implementation and airborne display requirements.
- Establish criteria for the selection and further consideration of candidate functions.

- Select top priority candidates through review with the Steering Group.

As a result of the review and selection process outlined above, message types for each functional area considered by the study team were developed. These are contained in Table 2-1. In addition, criteria were established both for service priority and simplicity of implementation. These are listed in Tables 2-2 and 2-3 respectively. Message types were grouped into service areas such as terminal control, enroute control, ground/local control, flight information services, and company communications, and ranked in accordance with the established criteria. The results of this ranking process are contained in Table 2-4. The study team and Steering Group then met to agree on the highest priority message types which are appropriate for data link test and demonstration. These higher priority message types are listed in Table 2-5.

Rationale for System Test - From discussions held with the Steering Committee and other individuals in the process of generating this report, a set of basic ground rules was developed for those concepts which were to be tested on DABS Data Link. All systems were selected for test on the basis of:

- SAFETY OF OPERATIONS
- UTILITY TO PILOT/ATC
- TIMELY FOR TEST
- SIMPLICITY OF IMPLEMENTATION

The primary reason for implementing any digital data link is to enhance the safety of aircraft operation. The communication of real-time weather products, e.g., hourly observations, to the cockpit and transmission of critical ATC messages in a fail-safe manner are the true benefits to the user in a data-link environment, and hence the priority candidates for test.

Although many candidate systems certainly contribute to the safety and utility of the pilot, primary consideration was given to those test systems whose planned date of development for testing was within the 1979 time frame. This report focuses on systems which have a near-term realizable benefit; nevertheless the test-bed facility will be flexible enough to absorb other candidate systems for future testing. A final factor is the desire to keep the prototype system as simple as possible, so that test implementation does not become an overriding consideration. It is recommended that wherever possible, the Data Link Program Office will test partial concepts with an eye towards further development, rather than wait until the full, complex system is available. Much needed, desirable information can be gained from a test of more simple components of a larger, complex system.

Other Considerations - The technology developed under this program will be applicable to the entire industry, both Commercial and General Aviation. Flexibility, and a capacity to function universally are the key criteria for the development of equipment to be used in aircraft. Although more sophisticated equipment will ultimately be developed for cockpit use, the present effort will be directed toward the 'least common denominator,' or that equipment which is acceptable for general use. Since a cockpit printer is capable of display of all messages, long and short, and appears to be a common element in all cockpit display complements, all display requirements will be directed towards a printer only as a minimum capability. If any of the test aircraft are to be equipped with more sophisticated display equipment, then further distinction can be made on display considerations. This same consideration can be made with respect to a keyboard entry device.

It is also recommended that a mini-computer be included in the ground equipment configuration to act as a pre-processor for the various sub-systems data which must be reformatted before it can be encoded by DABS, and perform the computations required to address any message to the appropriate aircraft.

TABLE 2-1. LIST OF MESSAGE TYPES

MESSAGE TYPES	UPLINK	DOWNLINK
CONTROL MESSAGE AUTOMATION	Frequency/Code Assignment Altimeter Setting Heading/Altitude Speed Instructions Holding Instructions Approach Clearance Request for Position Report MSAW Conflict Alert Metering and Spacing	Acknowledge Unable Pilot Request Pilot Report
FLIGHT INFORMATION SERVICES	ATIS/NOTAMS Predeparture Weather Severe Weather Advisory	Flight Plan Filing Weather Report
TERMINAL INFORMATION PROCESSING SYSTEM	ATIS/NOTAMS Flight Plan Clearance Beacon Code Assignment Standard Taxiway Route Runway Assignment Assigned Star Gate Assignment	Acknowledge Unable
WAKE VORTEX/ WIND SHEAR	High Altitude Winds Center Field Surface Winds Threshold Wind Change Vector Wind Change Shear Existence Max Shear Measurement Vortex Existence	
COMPANY COMMUNICATIONS	Flight Following Logistics Maintenance Pax Service	

N.B. Downlink transmissions, where indicated, are common to one or more Uplink transmissions, but not necessarily common to all Uplink transmissions. Also, Downlink transmissions may not require an Uplink response.

TABLE 2-2. SERVICE PRIORITY CRITERIA

1. SAFETY OF OPERATIONS
2. SEPARATION ASSURANCE
3. EFFICIENCY OF OPERATIONS
4. NEW OR IMPROVED SERVICE

TABLE 2-3. EASE OF IMPLEMENTATION CRITERIA

1. ALREADY PLANNED OR EXISTS
2. SLIGHT MODIFICATION TO EXISTING PLANS
3. MODIFICATION TO EXISTING PLANS
   ADDITIONAL DEVELOPMENT REQUIRED

TABLE 2-4. RESULTS OF RANKING PROCESS

TERMINAL CONTROL	SERVICE PRIORITY	EASE OF IMPLEMENTATION	PROGRAM AREA
Terminal MSAWS	1	1	Mod ARTS-III
Wind Shear Advisory	1	3	Wind Shear
Wake Vortex Advisory	1	3	Wake Vortex
Conflict Alert	2	4	Conflict Alert
Airborne Situation Display	2		
Metering and Spacing	3	4	M&S
Beacon Code Assignment	3	4	TIPS
Runway Assignments	3	4	TIPS
ENROUTE CONTROL			
Enroute MSAWS	1	2	MSAW
Alt Setting/Freq./Beacon Code	3	1	CMA
Conflict Alert	2	4	Conflict Alert
Flight Plan Amendment Delivery/Request	3	3	
Delay Estimates	3	3	
Enroute Metering/Profile Descent	3	4	Enroute Metering
GROUND/LOCAL CONTROL			
Takeoff Clearance Confirmation	1	4	TIPS
Runway/Taxi Assignment/Routing	1	4	TIPS
Predeparture Clearance Delivery	3	4	TIPS

TABLE 2-4. RESULTS OF RANKING PROCESS (Cont.)

FLIGHT INFORMATION SERVICES	SERVICE PRIORITY	EASE OF IMPLEMENTATION	PROGRAM AREA
ATIS/NOTAMS	1	3	FSS
Predeparture Weather	1	3	FSS
Severe Weather Advisory	1	3	FSS
Flight Plan Filing	3	3	FSS
Downlink Weather Info	5	3	FSS
COMPANY COMMUNICATIONS			
Flight Following	5	5	NONE
Logistics	5	5	NONE
Maintenance	5	5	NONE
Pax Service	5	5	NONE

TABLE 2-5. PRIORITY CANDIDATES FOR DATA LINK DEMO

ATIS/NOTAMS
PREDEPARTURE WEATHER
SEVERE WEATHER ADVISORY
TAKEOFF CLEARANCE CONFIRMATION
ALTITUDE ASSIGNMENT CONFIRMATION
DOWNLINK WEATHER INFO (PIREP)

3.0 RECOMMENDATIONS FOR TEST SYSTEMS

As stated previously, the primary considerations for each candidate test system were the safety and utility aspects, the timeliness of availability for test, and the simplicity of implementation. Where possible, the sources of data for each application are identified, along with the description of the flow of the data through the ATC system and a statement of the present and future status of automation.

3.1 EXCHANGE OF WEATHER DATA

There is general agreement within the pilot community that the presence of real-time weather information in the cockpit would be of great benefit. Until recently, there was little route oriented current information available to the pilot. Surface observation and forecast data obtained during a preflight briefing, augmented by in-flight FSS briefings, TWEB, and VOR recordings, was the only information available, and very often it was not current. This void has begun to be filled by the Enroute Flight Advisory System (EFAS) positions within Flight Service Stations (FSS), which provide real-time, in-flight, current weather reports to pilots within their coverage area. However, an 'Aviation Weather System Program Plan' was recently released (in draft form) which outlines the intended organization of weather-related activity (data acquisition, processing, communication and presentation) into a single integrated system capable of meeting near-term requirements and future expansion.

Many of the elements of the improved Aviation Weather System (AWES) readily lend themselves to data link applications. Under AWES, information which is more current and complete, will be more rapidly distributed in a format directly useful to pilots. The major focal point for real-time collection, monitoring, interpretation and dissemination of hazardous weather information will be concentrated at the ARTCC Weather Facility (CWEF) within each ARTCC around the country. The key improvements include a professional meteorological staff at each ARTCC to monitor weather developments and provide general weather briefings and hazardous weather advisory service to controllers, including PIREPS. Thus, the Data Link might be used to directly disseminate any information collected by CWEF personnel.

3.1.1 Uplink Weather

FSS Automation (FSSA) Program has developed a computer system which processes the same weather data available to the FSS specialist and disseminates it under text and voice response formats for direct access to pilots. This data base could be accessed to furnish pilots with route-oriented weather advisories containing hourly observations, terminal forecasts, winds aloft data, weather warnings, NOTAMS, PIREPS, and weather synopses.

The availability of this data would augment previously obtained data with more current weather information relevant to the needs of a pilot enroute.

One basic requirement for the request of weather information is a keyboard in the cockpit upon which alpha numeric data is entered. If one accepts this concept, then the implementation of the weather message interface is straight-forward. The pilot would formulate a request for weather on his keyboard device, transmit the request down the link, where the ground computer facility would format the request and communicate with the FSSA computer. The requested data would then return along the same path, up the data link, to be displayed in the cockpit.

Those elements of enroute weather which would be of great benefit to pilots are reports of thunderstorm activity, turbulence, icing levels and cloud tops. Under the AWES concept, this information will be available to CWEF personnel within each ARTCC from weather radar displays, communication with FSS EFAS positions, and PIREPS. It is recommended (in the "Aviation Weather System Program Plan") that the basic elements of the future CWEF facility be located at the ARTCC facility, i.e., a meteorologist with access to radar and pilot reported hazardous weather data. The CWEF personnel would collect and interpret reports, then construct messages for uplink to the appropriate test aircraft. Yet to be established are the various message formats, although they could basically follow the form of a PIREP, indicating observation time, source, location and description of the hazardous weather. The establishment of this service requires the close cooperation of NWS and the Aviation Weather groups within FAA, to make available a prototype version of the CWEF facility for test at NAFEC or take the DABSEF to where the prototype CWEF is located.

Routine terminal weather includes those items normally contained in an ATIS report, currently generated by controllers and broadcast continuously on a selected radio frequency. Current automation of the ATIS function is achieved through the AV-AWOS program, which will be capable of providing real-time observations in digital format. The set of data obtained from AV-AWOS (ceiling, visibility, precipitation, temperature, dewpoint, wind and altimeter) could be augmented by runway-in-use information and recent NOTAMS (entered by terminal controllers as needed). A pilot of a data link-equipped aircraft could request the ATIS report at his destination airport by keyboard entry of "ATIS/LOC." The ground computer system would route his request to the appropriate terminal facility.

3.1.2 Downlink Weather

Part of the dynamic data base which plays a significant role in the real-time assessment of hazardous weather are the in-flight reports filed by pilots (PIREPS). In the current aviation weather system, PIREPS are often used only by the facility receiving them on the ground, and not communicated to other elements of the aviation weather community. In the future, improved communications links and real-time assessment of PIREPS by meteorologists within the CWEF will make them more valuable, especially for short-lived, fast-moving phenomena.

There are two modes of reporting, manual and automatic. In the former case, a pilot may enter on a cockpit keyboard a report of hazardous weather encountered - thunderstorms, ising level, precipitation, cloud tops, and other phenomena and transmit it down the link. The pilot workload in this situation should be evaluated, as there are circumstances under which the pilot would not have time or the desire to enter data for transmission.

The automatic transmission of inflight data is the more desirable option because it reduces pilot workload. In 1966, the FAA demonstrated the Meteorological (MET)* data acqusition system, developed to support atmospheric studies, which was capable of measuring temperature, dewpoint, turbulence dissipation rate and structure coefficients, radio and barometric altitude, airspeed and winds aloft. Much of the sophistication of this equipment is beyond the means of GA users, but the concepts demonstrated should be explored further to indicate what data is capable of being automatically sensed and sent down the link with today's technology.

3.2 FLIGHT PLAN FILING

In the current ATC system, flight plans are filed either through 'bulk storage' or individual pilot contact. In the 'bulk storage' method used by commercial aviation all flight plans flown on schedule every day are automatically retrieved and activated without reentry of data on a daily basis. Conversely, individual pilots must file their flight plans by telephone or face-to-face contact with an FSS specialist, by calling a "fast-file" recording device over the telephone, or by air-to-ground communication to an FSS specialist, enroute or terminal controller. By any of these latter means, the plan must always be entered manually into the NAS system causing it to become a significant part of the labor-intensive ATC system. Part of the FSSA program is the development of a flight plan filing capability <u>directly</u> from the pilot through a user terminal into

*"Airborne Meteorological Instrumentation System and Data Reduction," "JB" McCollough, Larry K. Carpenter - March, 1975 (Report FAA-RD-75-69).

the FSSA computer facility and thence, into the NAS computer, with no manual interface. The FSSA computer will conduct the dialog with the user, elicit all entries, check for errors in format and logic, and transmit to the NAS system in a compatible format.

Pilot capability for flight plan alteration from the cockpit would allow more source of automation, and hence relieve the overload on the manual system. The FSSA program is currently developing the capability of filing flight plans via VRS (Voice Response System), with completion scheduled in the near future. Once the FSSA/NAS interface is established for the VRS. and later the PSB (Pilot Self Briefing) concept, it would be easy to access through the same Data Link/FSSA interface established for inflight weather.. As with that concept, flight plan filing, or alteration request, requires a keyboard in the cockpit to enter the various fields of data required of a flight plan.

3.3 GROUND CONTROL CLEARANCE DELIVERY

There are two aspects of tower control issuance of clearances which are suitable for Data Link test at this time: predeparture clearance and take-off clearance. Currently, Clearance Delivery (CD) receives predeparture clearances for filed aircraft and delivers the clearances to the waiting pilots by means of the voice communication channel. In issuing a flight plan clearance, CD may read part or all of the cleared flight plan to the pilot. Flight plan data is currently available to CD in the form of paper flight strips printed out by the FDEP (Flight Data Entry and Printer). Departure clearance must be amended to the flight plan to yield the full flight clearance.

The Terminal Information Processing System (TIPS) is a computer based system being developed by SRDS to replace the FDEP system, at least at the busier terminal areas. TIPS will replace the paper flight strip with a tabular flight data display and two data entry devices: an ARTS-like keyboard and a "quick action" device. The quick action device will permit each controller to do routine data manipulation, such as handoff, with a minimum of button pushing.

At present, it is envisioned that with TIPS, CD would still issue predeparture clearances to pilots by means of the voice communication channel. However, if TIPS were to interface with the DABS data link, predeparture clearance could be relayed directly to the pilot. CD would first verify the correctness of flight plans on the TIPS display and then use the "quick action" device to transmit them to the pilots by means of the DABS data link.

Use of the data link to transmit the predeparture clearance would reduce clearance delivery voice channel loading, which would increase the capacity of the controller position, and lessen the chance of misunderstanding between pilot and clearance delivery by providing a hard copy (printed) of the cleared flight plan, which may contain modifications and special instructions, to the pilot.

Providing hard copy would reduce pilot workload and the possibility of pilot error.

As with weather information requested, before a TIPS/DABS interface can be seriously considered for the predeparture clearance function, it must be determined if the airborne, line-of-sight DABS system can be used on the airport surface, particularly in the terminal ramp and gate areas. The coverage of the DABS data link on the airport surface needs to be determined for both the immediate airport and for remote airports up to 20 miles away.

The proposed SRDS Program schedule calls for a prototype TIPS unit to be tested at NAFEC sometime during CY79 and CY80. The prototype unit will be primarily concerned with the current terminal area environment. At present, the plans for the unit do not call for interfaces with other new systems currently under development, such as DABS. The feasibility of interfacing DABS and TIPS for testing at NAFEC will be further investigated.

In the current ATC system, the take-off clearance is given to the pilot over the voice channel. The FAA has developed a capability to give the pilot a non-verbal confirmation of the issuance of take-off clearance, using a visual signal alongside of the runway activated by the local controller. It is intended to be installed nationwide at all tower-controlled airports. The benefit to aircraft safety is that there is the possibility of misunderstanding the issuance of take-off clearance in the present system, and a non-verbal confirmation of the clearance could prevent accidents such as the disaster at Tenerife. For those aircraft equipped with Data Link, the confirmation could take the form of a short message on the cockpit display or printer.

The system under development, VCOVTC (for Visual Confirmation Of Takeoff Clearance), is still in the design stage, with Phase I testing scheduled for early 1978 at NAFEC. For that test, lights will be installed at intersections along the active runway, controlled from the tower. Coordination between the FAA Data Link Program Office and FAA Systems Research & Development Service, could result in an operational test of takeoff clearance delivery.

Another consideration is the coverage of the DABS Data Link in the the terminal environment (ramp and gate area), which could perhaps be determined through system sub-test before the full system is assembled.

3.4 ENROUTE ASSIGNED ALTITUDE

Under the present NAS system all commercial aircraft, and all aircraft that fly in positive controlled airspace are required to carry altitude read-out equipment. The altitude read-out is displayed on the radar's aircraft data block — together with the assigned altitude manually inputted by the controller — showing the various changing altitudes, whether the aircraft is climbing or descending. When the aircraft levels at its assigned altitude, the altitude read-out and the assigned altitude are the same, and only the assigned altitude will be displayed. There is, therefore, under the present system, digitized confirmation of the assigned altitude, in the context just described. The problem of transfer of control, from sector to sector, is still unresolved.

A recurring problem in enroute traffic control is a misunderstanding between the pilot and controller concerning the altitude to which an aircraft has been cleared. Obviously this can result in two aircraft occupying the same flight level or altitude in a potential conflict situation before the controller becomes aware of the misunderstanding. The present solution to this problem is to require that the pilots confirm the assigned altitude by means of voice communications. Although this is done routinely in today's system, misunderstandings still occur. Therefore, a more positive means of confirmation which includes a clear record of the altitude assignment is desired. The assigned altitude experiment addresses the voice confirmation problem.

Air Carrier aircraft are required to carry an Altitude Alert System (AAS) which is used for setting either the assigned enroute altitude or a pre-selected minimum approach altitude. Visual and audio alerts are given if the aircraft deviates from the altitude by more than a selected range. The AAS, in conjunction with the DABS Data Link, could be used to confirm the enroute altitude assignment. The pilot, after selecting an appropriate range of sensitivity, would set the assigned altitude on the AAS instrument. A digital assigned altitude message would then be transmitted up the data link for confirmation of the pilot. The NAS computer would compare the assigned altitudes entered by the controller and the pilot. A confirmation or discrepancy alert symbol on the controller display would then be activated. In the event of a discrepancy or no response from the pilot, the controller would use voice communications to resolve the situation or, alternatively, send a REQUEST ALTITUDE CONFIRMATION message through the data link uplink of assigned altitude which appears in the data block on the radar display.

In order to implement the assigned altitude confirmation function, three existing systems would require modification. The AAS would require the addition of a CONFIRM pushbutton, a digital timer for measuring a preset time interval, and an altitude digital encoder. Some manufacturers currently include an encoder with the system. The encoder output would be connected to the Data Link transmitter. Ten digital bits of information would provide an altitude range from 100 feet (LSB) to 51,200 feet (MSB). Additional bits would be required for sign, flags, and assigned identification code.

In the 9020 NAS Computer, additional software would be required to store and compare the confirmed altitude received from the data link with the assigned altitude entered by the controller. In addition, a message indicating either confirmation or discrepancy would be generated and sent to the controller position.

On the controller display, an additional symbol indicating to the controller either confirmation or a discrepancy in the assigned altitude would be required. The symbol could be located either on the Plan View Display (PVD) or on the tabular display.

4.0 OTHER CANDIDATE DABS DATA LINK FUNCTIONS

In the early phases of the study conducted by TSC, many functions and systems were considered as possible candidates for the DABS Data Link development tests. Some were systematically eliminated from consideration for the initial testing for various reasons, for example, IPC, or as it is now known, ATARS. Other functions such as Conflict Resolution, Metering and Spacing, and Flight Plan Probe have been temporarily set aside until such time as each research & development effort evolves to the point where integration within the DABS system is more feasible. All of them are under development within SRDS and will be available for Data Link testing at various times. A brief description of these functions and their development status follows.

4.1 WAKE VORTEX/WIND SHEAR ADVISORY

The existing Vortex Advisory System is a meteorological-based system that will provide the air traffic controller with a precise definition of when separations between arriving aircraft can be reduced from the standard IFR separations (3 miles normally, 5-6 miles for heavy aircraft). The data utilized by the system (a serial data stream) consist of wind velocities from a number of meteorological towers located at the four corners of the airport perimeter and the center of the field; the velocities are averaged and compared with an algorithm in a microprocessor. The output of the microprocessors is put on a data bus; the controller or summary display addresses the appropriate frames in the data stream to obtain the separation condition (3 mile or 5-6 miles) for the specific runway of interest, along with the wind velocity, direction, and gust level for the specific runway. The summary display takes the wind velocity direction and gust level reading, along with the separation condition, from the data bus for each of the meterological towers and displays the data through a series of stacked LED (Light Emitting Diode) readouts.

It is intended that the Wind Shear display requirements will be combined with VAS (Vortex Advisory System). This addition will add a wind shear alert, i.e., an indication of two or more wind readings which, when compared, indicate a vector difference of 15 knots or greater.

The data from the Vortex Advisory System is needed only by the controllers so that they can set separations for the selected operating runways. There is no current or planned capability to provide the wind data for just the operating runway; the controller must select the runway and verbally transmit the selected wind data.

In the design change to incorporate the wind shear display requirements, provision could be made to provide the wind velocity of those towers whose difference exceed 15 knots.

This concept is not recommended for implementation and test at this time. Although there can be little doubt that real-time readout of the wind vector above the threshold of the landing runway would increase the safety of the aircraft, the VAS/SWIMS (Vortex Advisory System/Surface Wind Instrument Measurement System) in its current development does not deliver such data. Its primary purpose is to advise the controller through a comprehensive display, with no provision for outputting selected (runway) data. Also, there is no current plan to install an integrated VAS/SWIMS at NAFEC, as the prototype systems will undergo evaluation at airports around the country.

Although this program in its present state of development does not produce the desired data most beneficial to the pilot, i.e., wind velocity at the runway threshold, which appears a minor difficulty, the benefits to be derived from the program once it has reached the testing stage are expected to be considerable, and will afford one of the most beneficial uses in data link transmissions.

4.2 CONFLICT ALERT AND RESOLUTION

Conflict alert is a software program within either the NAS or ARTS operational programs which predicts a violation of separation criteria between two aircraft and provides a warning to the controller. It signals an advanced state of conflict and displays resolution advisories to the controller. In generating the recommended advisories, the floght plan intent of the aircraft is taken into account. and a check is made to assure that a new conflict will not results. The controller exervices final authority in issuing voice commands to the aircraft involved.

Conflict Resolution Messages for the DABS Data Link - Conflict resolution messages are in the form of maneuver commands, i.e., turn right/left, climb/dive, or reduce/increase speed. In all likelihood these messages would first be displayed to the controller who, after analysing the situation, would then issue appropriate commands to one or both of the aircraft. Upon receipt of the command, the pilot would respond with ACKNOWLEDGE or UNABLE.

Program Status - A conflict alert function is now operational in the NAS enroute system for IFR/IFR potential conflicts. Ongoing development programs are designed to improve this function, particularly for aircraft in turns and for intruder aircraft.

Conflict alert and resolution for the ARTS system is a staged development program with final software testing schedule for NAFEC in 1979.

Before resolution messages can be considered appropriate for Data Link developmental testing, the interfaces between the software, the controller, and the pilot must be evaluated.

4.3 METERING AND SPACING

Metering and spacing is a combination of software programs designed to improve the use of available terminal facilities by dynamically regulating air traffic both in the enroute and the terminal areas. Algorithms compute the optimum arrival times over fixes, the scheduled landing sequences and landing times, and display this information to controllers. Adjustments in aircraft flight paths are also computed and delay absorbtion advisories are given to the controllers.

Metering and Spacing Messages for DABS Data Link - Maneuver advisories to the controller consist of aircraft speed changes, point of descent initiation, rate of decent, and holding instructions. These messages would first be displayed to the controller who, after confirming the message, would then issue appropriate commands over the data link to the aircraft. Upon receipt of the command, the pilot would respond with ACKNOWLEDGE or UNABLE.

Program Status - A preliminary version of terminal Metering and Spacing is undergoing test and evaluation at NAFEC and at the Denver TRACON. This version provides for arrivals only and a single runway configuration. Ongoing development programs both for terminal and enroute areas will expand the capabilities to a more general terminal configuration, will provide a logical interface between enroute and terminal operations, and will generate delay absorbtion advisories for the controllers. Operational testing of the advanced programs is scheduled for the 1980/1981 time frame.

Before metering and spacing messages can be considered appropriate for Data Link developmental testing, the interfaces between the software, the controller, and the pilot must be evaluated.

4.4 FLIGHT PLAN PROBE

Flight PLAN PROBE is a software program for the NAS enroute operational system designed to project an aircraft's intended path through a sector or, possibly, through an entire center and search for potential conflicts. A conflict notice is given to the controller. A controller may then input a revised flight plan and a further search will be made. Future enhancements may include computer generation of alternative flight plans.

Flight Plan Probe Messages for the DABS Data Link - The end objective of the Flight Plan Probe function is to generate a revised, conflict-free flight plan for an aircraft. The revised flight plan must be transmitted to the aircraft. Revisions to a previously issued flight plan typically require up to 20 alpha numeric characters and can be displayed visually to the pilot. An ACKNOWLEDGE or UNABLE response on the downlink would be required. Obviously the transmittal of flight plan changes over the data link is not dependent on the Flight Plan Probe function; controllers issue modifications to flight plans for a variety of reasons. Therefore this function is not a logical candidate for Data Link development testing.

Program Status - Current developmental efforts are directed toward the detection of potential conflicts and issuing an alert to the controller. It is left to the controller to devise alternative plans and seek a conflict-free solution. Although computer-generated solutions are a long range goal of this effort, there are no firm plans for its achievement. The program as currently structured will undergo operational testing in early 1979.

5.0 CHARACTERISTICS OF DABS DATA LINK

This section attempts to consolidate some of the available information on the existing DABS System Specifications, the implementations, and test concepts derived primarily from the Lincoln Labororatory (L.L.) Project Reports, and discussions with technical personnel from L. L., NAFEC, and TSC.

Studies have been conducted by FAA, L.L., TSC, and others, to establish the requirements for DABS System design and applications. Many reports and memos cover the details that resulted from these efforts and the general requirements of a DABS Data Link System are stated in Section 2 of this report. One aspect of the DABS System that could benefit from some additional effort is the area of DABS Data Link applicability.

Lincoln Labs, in direct support of FAA/SRDS, has developed a complete DABS System that is implemented to checkout and test the DABS concept, including the ground based sensor stations and the transponder avionics. The current systems are used by Lincoln Labs for validation tests to obtain error statistics of the DABS monopulse radar and to demonstrate collision avioidance with the use of Data Link got ATARS (formerly IPC/PWI). Some of the established performance parameters for the DABS System are summarized in TABLE 5-1.

LINCOLN LABS DABS EXPERIMENTAL FACILITY (DABSEF)

The L.L. DABSEF is essentially the ground based facilities that include the antenna system, transmitter/receiver and several processors required to perform surveillance and to relay data link messages. Figure 5-1 shows a Block Diagram of the DABSEF. An existing DABSEF sensor facility is maintained at Lincoln Labs that is equipped with the monopulse radar and has been used for the test programs.

The DABSEF facility is also equipped with a 20 inch CRT section display that has been used in over a thousand planned collision avoidance tests with GA aircraft. These tests were performed in the Hanscom Field area.

TABLE 5-1. LL DABS CHARACTERISTICS

INTERROGATIONS AND REPLY (BOTH)

- Message Function - Surveillance and Data
- Message Length - 112 BITS
- Data Link (SM) - 56 BITS
- Address and Parity - 24 BITS
- Surveillance Data - 16 BITS
- Error Protection and Parity Check
- Miscellaneous - (16 BITS-Parity)
- Data Link (ELM) - 80 BITS

INTERROGATIONS (SENSOR)

- Frequency - 1030 MHz
- Modulation - DPSK
- Data Rate - 4 Mbps
- Data Link (SM) - 56 BITS

REPLY (TRANSPONDER)

- Frequency - 1090 MHz
- Modulation - PPM
- Data Rate - 1 Mbps.
- Configuration - Main Unit (Remote Installation) and Control Unit (in cockpit)

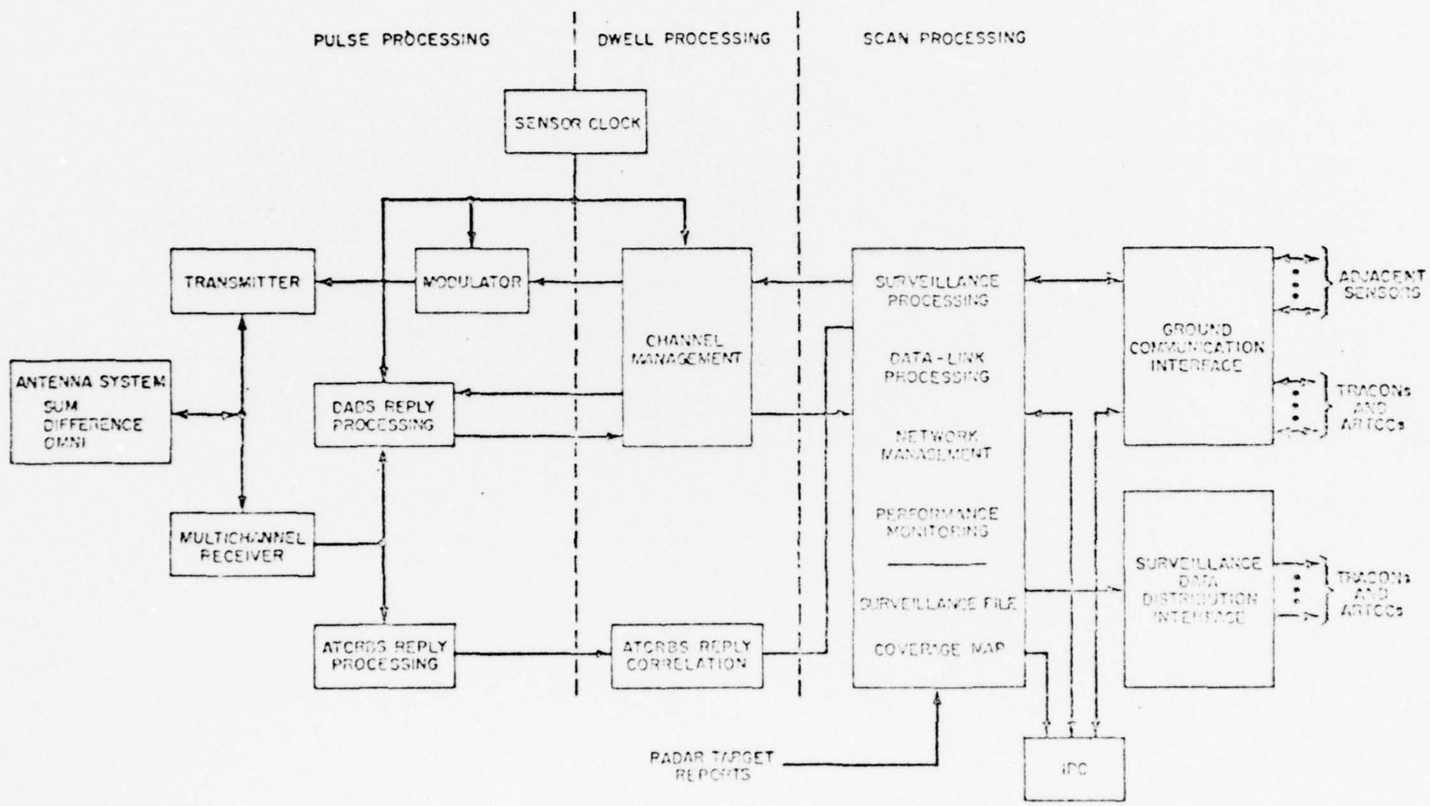

FIGURE 5-1. DABS SENSOR FUNCTIONAL BLOCK DIAGRAM

Lincoln Labs DABS Avionics

The main components of the existing Lincoln Labs DABS Avionics System are the aircraft antennas (L-Band), the Transponder consisting of: receiver, transmitter, DPSK Demodulator, modulator, and signal processors, and the Data Link message display devices (IPC/PWI and ATC).

The existing L.L. Transponder receives and decodes ATCRBS and DABS interrogations (surveillance and Data Link). The L.L. transponder is capable of handling only the 56-BIT SM (short message) format and not the ELM* (extended length message). Ten of these transponders were procured by L.L. from Bendix Avionics (Ft. Lauderdale, FL) and have been used in the L.L. test program. Plans are to collect these transponders and use them in the 1979 NAFEC test program.

Lincoln Lab DABS System Test

A considerable amount of actual testing has been done with the L.L. DABS System using the DABSEF and TMF sensor facilities and single engine GA aircraft. Data has been presented showing measured aircraft densities, interference conditions, effects of reflections and propagation blockages by buildings, and surveillance accuracies. Demonstrations were witnessed showing the use of DABS Data Link in collision avoidance involving two GA test aircraft. A series of planned near-miss intercepts, within 200 feet altitude separation, were shown on a TPX-42 traffic situation display. Figure 5-2, DABSEF IPC FLIGHT TEST BED, is included to show flight test bed set-up. Future test support requirements for L.L. will probably be in support of development of test and evaluation plans for the DABS Data Link application. TSC is presently involved in this effort in support of FAA/SRDS.

*Reference: Project Report, ATC-34, "Provisional Data Link Interface Standard for the DABS Transponder," MIT/Lincoln Laboratory, 25 April 1974 (Report FAA-RD-74-64).

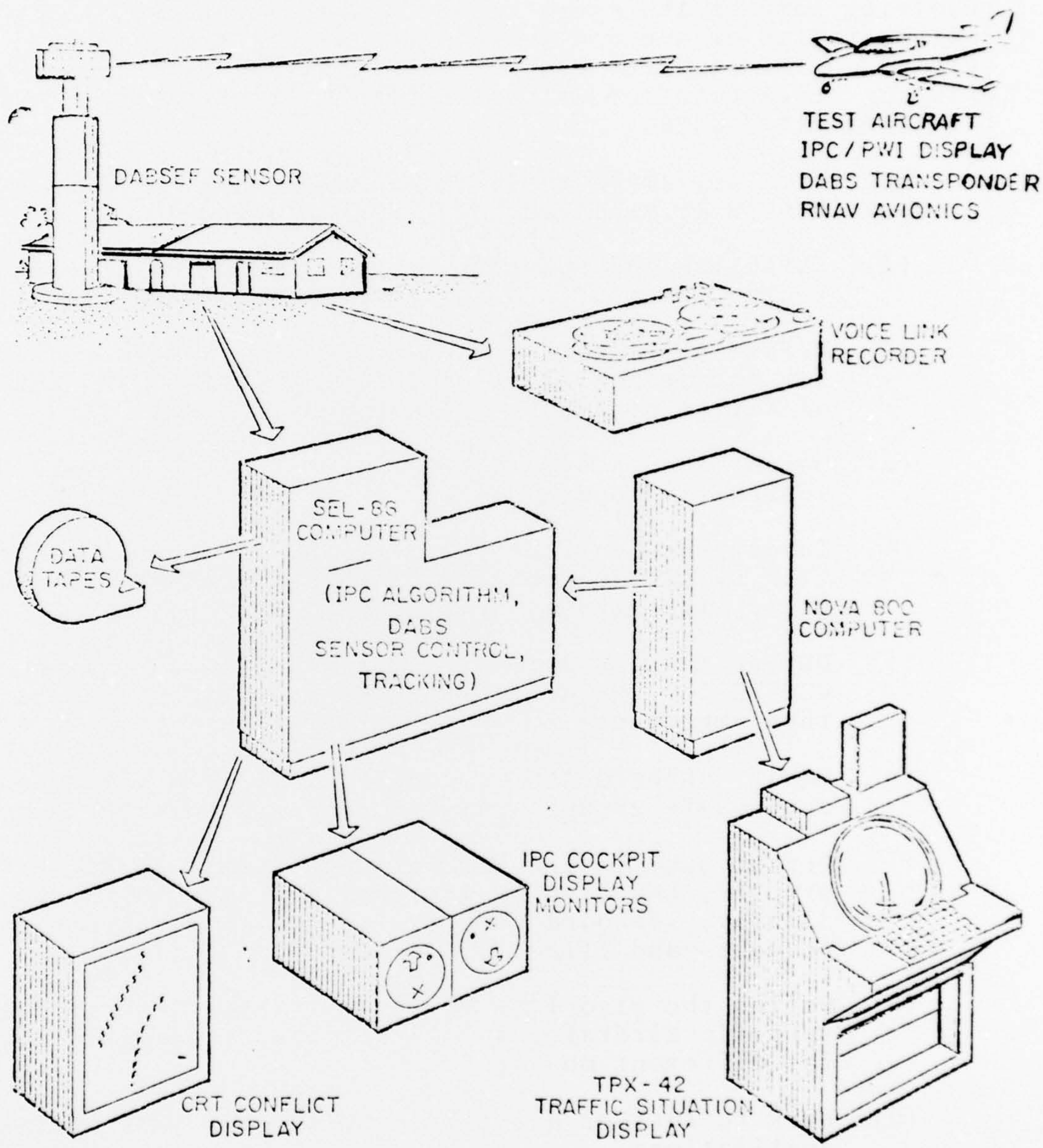

FIGURE 5-2. DABSEF IPC FLIGHT TEST BED

6.0 FUTURE WORK

There is much work remaining in the areas of (1) defining the required interface between the DABS Data Link and each candidate subsystem, e.g., data format, content, and rate; (2) resolving some of the operational considerations which may prevent implementation of a given sub-system at this time; and (3) actually setting up the required equipment on-site and interfacing it with existing development/operational systems which supply (or receive) the transmitted data.

Specifically, among those items which must be performed (or questions to be answered) are the following:

(1) Establish the operational requirements of the ARTCC Weather Facility at NAFEC, and integrate with DABS.

(2) Define the interface between DABS and the FSSA program, for the transmission of inflight weather and the filing of flight plans, then implement.

(3) Define the interface between DABS and the AV-AWOS sensors/controller inputs needed for automatic ATIS delivery.

(4) Investigate further state-of-the-art avionics for downlink of airborne observed weather parameters, and integrate with DABS aircraft equipment.

(5) Define the operational interface between DABS and TIPS/VCOVTC for the delivery of ground clearance commands, then implement.

(6) Modify onboard AAS to downlink assigned altitude, and accomodate ground system to display this parameter.

(7) Define onboard I/O hardware complement to be tested-printer, LED display integrated within multi-function display, keyboard for pilot entry of weather and ATIS requests and flight plan filing.

(8) Define the algorithm which will allow DABS to address specific aircraft, or all aircraft in a given sector, for different message types.

(9) Work to further quantify benefits and justify the applications.