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DABS Sensor Interactions with ATC Facilities

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16. Abstract

This document presents, on a functional level, the interactions that occur between a DABS sensor and an ATC facility (terminal or enroute) in order to make full use of the capabilities provided by the addition of DABS sensors to the ATC system. There are three functions of the interactions: (1) handle surveillance reports from the DABS site, (2) handle the two-way digital communications messages between pilots and controllers, and (3) handle a variety of control data messages between the two sites. For each kind of interaction, the actions taken by the DABS sensor are summarized, the messages involved in the transaction are defined, and suggestions are made concerning possible appropriate actions by the ATC facility. The latter include message generation and display, data processing, and controller and system manager activities.

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1.0 INTRODUCTION

Introduction of the Discrete Address Beacon System (DABS) represents a main element in realizing the objectives of the Upgraded Third Generation Air Traffic Control system. DABS not only resolves basic problems inherent in the present beacon surveillance system (ATCRBS), but it realizes a low-cost, high capacity and very reliable ground-air-ground data link. A very significant feature of DABS is that human intervention is not needed to establish or maintain surveillance or communications. DABS sensors, where possible, are connected and form a network to improve the quality and reliability of the data link and continuity of surveillance.

Intermittent Positive Control (IPC), collocated with DABS, maintains a limited form of control in the form of automatically generated messages uplinked to aircraft that are in potential danger of collision. The control maintained by IPC through DABS is intended for VFR as well as IFR aircraft. For IFR aircraft, the primary responsibility for control lies with the controller at the ATC facility. To allow him to effectively exercise this responsibility, the DABS sensor makes available to him all relevant information it possesses (all surveillance data being gathered, duplicates of IPC messages, and the use of its data link). Communication between the ATC facility and DABS is effected by means of an interface consisting of two-way ground communications for message exchange, and one-way DABS-to-NAS ground communications for surveillance reports.

The presence of DABS implies modifications to the existing NAS system. This document presents the type of information that DABS provides to the ATC facility and what the intended usage is. Section 2 includes the characteristics and use of surveillance reports. Section 3 presents the exchange of messages between the ATC facility and an aircraft by means of the DABS air-ground data link. Section 4 describes information exchanges between DABS and ATC facilities to proceed with control functions.

This document complements FAA-RD-74-63-Rev. 1 entitled, "Provisional Message Formats for the DABS/NAS Interface" [Ref. 1].

2.0 SURVEILLANCE

2.1 Characteristics of DABS Sensor Surveillance Data

An ATC facility connected to a DABS sensor will receive surveillance reports on all aircraft which are observed within the coverage area of the sensor and within the area of interest of the facility. The reports are issued once per scan for each aircraft and are delivered to the ATC facility by means of a one-way data link that is specifically provided for this purpose. The contents of the report and its format depend on the characteristics of the surveillance measurement. A report may derive from (1) replies from a DABS transponder, (2) replies from an ATCRBS transponder, (3) returns from a collocated primary radar, and (4) other Production Common Digitizer (PCD) messages. All report formats are based on current PCD formats, modified where necessary.

Beacon reports, whether based on DABS or ATCRBS replies, contain basic surveillance data in common: 15 bits of range information (to a precision 0.0078 nmi or approximately 50 feet), 13 bits of azimuth (to 0.044 degree or 0.5 ACP), and, whenever available, 12 bits of altitude (to 100 feet). Range and azimuth data are raw measurements that are not smoothed by the sensor tracker. Altitude data are formatted and converted from Mode C coding to a signed binary integer, but are not pressure corrected. Target identification data are always present, although in different forms for DABS and ATCRBS reports. Other information (for each type of report) included in various types of surveillance reports is provided in subsections below.

2.1.1 Reporting Delay

Surveillance reports are available for transmission to the ATC facility not later than 3/32 of an antenna scan period (3/16 of a scan for any back-to-back antenna) after the target measurement. For a 4-sec rotator, this maximum delay would be 3/8 sec for either a single-face antenna or a back-to-back configuration. Storage delay is reported as at present by means of Time in Storage data (quantized to 1/8 sec).

2.1.2 Coverage Assignment and Dissemination

In general, ATC facilities may expect to receive reports on a given aircraft from more than one sensor. For aircraft whose reports are based on ATCRBS replies or primary radar returns, this situation is similar to that of a present-day ARTCC that may receive several reports on an aircraft from different sensors. DABS sensors that share overlapping coverage areas are connected by data links to form a network, and one of the tasks performed by the network is the management of multiple coverage [Ref. 2]. Multiplicity of coverage will ordinarily be limited to two sensors, although in some regions of the airspace (near DABS coverage boundaries) there may be additional coverage. The sensors cooperatively manage assignments in such a way that, for a given DABS target at a given time, one and only one sensor is designated as "primary".* Other DABS sensors that are "secondary" (there may be still other sensors that have coverage but

*DABS "primary status" should not be confused with "primary radar." In this report, the term "primary radar" is not used further.

are not permitted to interrogate the target). The primary assignment is based mainly on geography, with provision for dynamic reassignment in case of temporary loss of the primary air-ground link or of sensor overload or failure. Within the DABS network, primary status implies that a sensor is permitted to carry out certain exclusive functions (e.g., readout of pilot downlink messages, delivery of altitude echo, and synchronized interrogations). Primary status may be regarded as indicating to the ATC facility which DABS sensor is currently providing the highest reliability link to the aircraft for both surveillance and data link purposes. Every DABS based surveillance report contains an indicator (the 1-bit "P/S" tag) of primary/secondary status.

More generally, the purpose of the DABS network management function is to maintain the continuity of DABS service, for both surveillance and communications as aircraft leave the coverage areas of some DABS sensors and enter others, and in cases of overload or failure (whether of sensors or data links). This function is carried out in a way that does not require involvement of ATC facilities or other users. Information on the status of DABS sensors is, however, available at ATC facilities so that they may monitor the DABS system.

Related to coverage assignment is the DABS function of data dissemination. Unlike present beacon interrogators, a DABS sensor does not necessarily transmit all of its aircraft reports to a particular ATC facility. Instead, it uses a data dissemination map to transmit reports on only those aircraft located within the area of interest to the ATC facility. Of course, if the DABS sensor's coverage area is fully imbedded in the ATC facility's control area, all of that sensor's reports are sent and the dissemination function is trivial. For the case of a sensor near a control boundary, the dissemination map will prevent the delivery of reports that are not of interest to the ATC facility recipient. The dissemination decision is based on simple criteria of range, azimuth and altitude, with azimuth divided into 32 sectors. This dissemination map is normally fixed, but may change as part of the backup operation controlled by the network management function in cases of sensor overload or failure. Specifically, if a sensor is assigned coverage in a region where it does not normally provide surveillance, its dissemination map will be modified so that reports are sent to whichever ATC facilities need the information.

Ordinarily, a sensor will disseminate local data only; that is, if a target track is in coast because of link failure, then no reports will be disseminated for that scan. This is true even if the track is being maintained by external data sent from another DABS sensor. However, under certain circumstances, surveillance data originating with another sensor will be forwarded to an ATC facility, as part of the "data relay mode." The conditions governing such relaying are as follows:

1) As part of site adaptation, a data relay mode has been defined designating the DABS sensor as the "relaying sensor" with respect to a particular second DABS sensor (the "unconnected sensor") and a particular ATC facility (the "unconnected ATC"). In order to be selected for this mode, the unconnected sensor and the relaying sensor must share some overlapping coverage and be connected by ground data links, while the unconnected sensor and the unconnected ATC do not have a direct data link.

2) The track of a particular DABS or ATCRBS target is in a coast state and has been updated during the current scan by surveillance data (in the form of a "track data" message) from the unconnected sensor.

Thus, the relaying of surveillance data is highly specific, being limited to a pre-selected ground configuration and to a particular target situation. When the air-ground link recovers and local data are available, relaying ends.

2.1.3 Surveillance Report Types

Surveillance reports utilize formats and coding which are modified versions of those presently used for PCD messages. Each report is composed of 13-bit words, of which 12 are data bits and the 13th is a parity bit. Reports are either 52 bits (4 words) or 91 bits (7 words) in length, with codes which serve to identify report type contained in the first word. Appendix A presents complete formats for the various types of surveillance messages. The types and the particular bit patterns that serve to identify them are summarized here:

1) Beacon targets (bits 2, 3 = 11)
   a) ATCRBS (bit 4 = 0)
   b) DABS (bit 4 = 1)

2) Radar targets and other PCD reports (bits 2, 3 = 00)
   a) Search report (radar target)(bits 4-7 = 1101)
   b) Strobe (bits 4-7 = 1100)
   c) Map (bits 4-7 = 0000)
   d) Status (bits 4-7 = 0110)
   e) Search RTQC Target (bits 4-7 = 1001)

Note that the beacon messages have a long (91-bit) format, whereas all the others have a short (52-bit) format; thus bits 2 and 3 serve as a length indicator. All of the short report types (otherwise referred to as PCD reports) use present PCD standard formats, and these message formats are not altered by processing in the DABS sensor. The actual data content of a PCD message, however, is affected in one instance by DABS processing, i.e., the addition of a collimation correction to the value of radar azimuth and range as received from the PCD. The collimation correction is intended to eliminate bias errors between the radar and the beacon antennas and is equivalent to the correction presently performed in NAS. Because the PCD formats are not affected by DABS, these messages are not discussed further here. The character of the information included in beacon reports is described in the next two subsections.

2.1.4 ATCRBS-Equipped Aircraft

In addition to data pertaining to range, azimuth, altitude (when Mode C replies are available), and storage time, an ATCRBS aircraft report from a DABS sensor includes several additional data fields that are the same as those in a present-day beacon report and a few new ones. The familiar data fields include indicator bits (Test, Mode 3/A, Mode C, SPI, Radar Reinforcement, Code 7700, Code 7600, and FAA) and one longer field, the 12-bit Mode 3/A code (when available). Each of these fields contains data that is not affected by DABS processing. As with the present beacon system, the presence of a Radar Reinforcement will normally cause DABS to suppress the radar report that correlates with the beacon report. The new ATCRBS report data fields include the ATCRBS Surveillance File Number, Confidence, Code in Transition, False Target, Radar Substitution, Run Length and Data Relay. Each of these is discussed in the following paragraphs.

The ATCRBS Surveillance File Number is a binary integer that represents the sequentially-assigned number used within the DABS software to identify a particular aircraft track. The presence of a nonzero value in this field indicates that the ATCRBS replies being reported have been successfully correlated with an existing track. The number has no intrinsic significance, but it does provide a reference number for a given aircraft, which is "locally unique" whether or not the aircraft is replying with a discrete code. "Locally unique" means that two tracks will not have the same number at a given time within a single sensor. The assignment of these numbers is not coordinated among sensors, so that the same aircraft reported by two sensors will have independently chosen numbers. Also, within a sensor, the number assignment is reset after the maximum value has been reached; enough bits are available (12) so that duplication on simultaneously active tracks will not occur. The inclusion of a Surveillance File Number in a report is the result of a target-to-track correlation process.

Confidence is a 1-bit indicator that denotes whether or not the target-to-track correlation has been performed with high or low confidence; more specifically, whether or not correlation was successful using the smallest range-azimuth correlation box. Of course, this indicator has significance only when a correlation is reported, as shown by a nonzero Surveillance File Number.

Code in Transition is another 1-bit tag, which, when set, indicates that the report is based on Mode 3/A replies, of which the code value did not match that of the track code although all other requirements for correlation were met. Therefore, the report and the track are considered to be correlated. Only the track code is reported, and it may be expected to differ from that of later scans.

False Target is a 1-bit tag that indicates when a report has been identified as being caused by reflection from a building or other terrain feature. Such reports will correspond to valid reports from the same aircraft but will have erroneous range and azimuth values. Because of the azimuth error, false targets will be reported either earlier or later in the scan than the true target report.

Radar Substitution is a 1-bit tag that partially redefines the report format. When set, it indicates that the report contains radar data rather than beacon data. This will occur when two conditions arise: (1) no beacon replies that correlate with a particular ATCRBS track are received on the current scan, and (2) radar returns are received that do correlate with that track. Under these conditions, the radar data are reported using the modified ATCRBS format rather than the usual PCD "Search" message so that the track correlation can be indicated (using the Surveillance Track File Number). Other data fields in the Radar Substitution message that derive strictly from ATCRBS returns are not used, and of course the reported range and azimuth come from the radar measurement. To complete the set of information normally included in a search message, the Run Length (3 bits, to a precision of 4 ACP) is also included. This field replaces a portion of the Mode C altitude field, which is not available in the case of Radar Substitution.

Data Relay is a one-bit indicator which, when set, indicates that the report has originated with an unconnected sensor. Such a report is not different from a local report in its principal data fields; range and azimuth have been converted to local sensor coordinates and the position estimated for the time of local measurement; Mode 3/A code and Mode C altitude are not affected; Surveillance File Number is given for the local (relaying) sensor. Other data fields are unaffected, except that Radar Substitution, Confidence, Code in Transition and False Target are not used. Correlating radar data are used only to indicate reinforcement.

2.1.5 DABS-Equipped Aircraft

As mentioned in paragraph 2.1, DABS reports include range, azimuth, storage time, P/S (primary/secondary) status, and (usually) Mode C altitude as included in ATCRBS reports. Altitude will be present whenever the report is based on roll-call replies, the normal surveillance mode. During acquisition, however, replies from a DABS transponder may consist of only All-Call replies, which do not provide altitude. The presence of altitude is indicated by a 1-bit "Mode C" tag, as in ATCRBS reports. DABS reports also include Codes 7700 and 7600, Radar Reinforcement, Radar Substitution, Run Length, and Data Relay fields the same as those designated for ATCRBS.

Other types of information provided in a DABS report are DABS Address, Alert, and FR. These are discussed in the following paragraphs.

DABS address is the 24-bit code that uniquely identifies each DABS transponder. Since this address easily provides very high confidence correlation of replies to tracks, no other ID data are needed or included (such as Mode 3/A codes or Surveillance File Numbers). Provision is made for handling the extremely low probability error condition of two targets having the same DABS address; this is discussed in Section 4. The coding scheme for DABS addresses is designed to encode all or part of the registration number (tail number) of the aircraft in which the transponder is installed. (See reference 3 for a recommended scheme for this type of code assignment.)

"Alert" is a 1-bit field containing a pilot's emergency signal. It is set automatically whenever the ATCRBS code on the transponder has been set to 7600 or 7700; in this case the Alert signal is reported redundantly. It may also be set directly by the pilot regardless of his code value. In either case, the Alert setting causes the DABS sensor to interrogate the aircraft as soon as possible for the purpose of code readout. The code received is transmitted to the ATC facility by a communications message (see Section 3).

Flight Rules ("FR") is a 1-bit tag derived from pilot input, indicating that the aircraft is flying under IFR or VFR rules. FR is included in surveillance reports primarily for the use of the IPC function, but may also be helpful to the ATC facility.

For a report resulting from the data relay mode, the various data fields are to be interpreted as for an ATCRBS data relay report (2.1.4). Other fields which are unique to DABS, but which cannot be supplied on the basis of a track data message, are not used. These include: P/S, Alert, and FR.

2.1.6 Radar Targets

The characteristics of radar reports have already been described in the preceding subsections. It may be useful to summarize here the rules that determine the methods by which radar returns are reported:

1) If the radar returns correlate with either a DABS or an ATCRBS beacon report, the beacon report is tagged as "Radar Reinforced" and the radar measurements are not separately reported.

2) If the radar returns correlate with a beacon track and beacon replies from the current scan are missing, the radar data are reported as a "Radar Substitution" message.

3) If the radar replies do not correlate, the data are sent as a Search message.

2.1.7 Summary

Surveillance processing in a DABS sensor operates with the goal of providing the ATC facility with exactly one report per scan on every aircraft within the data dissemination boundaries. This goal will not always be met, since a radar correlation failure will cause an extra report to be issued and an air-ground link failure may prevent any report. Each report will be one of the following four types:

1) A DABS report, regardless of the sensor track state, for each replying DABS transponder.

2) An ATCRBS report, for each replying ATCRBS transponder, with or without a Surveillance File Number, depending on whether or not the replies correlate with a track.

3) A Radar Substitution report for either a nonreplying DABS-equipped or a nonreplying ATCRBS-equipped aircraft when the radar return correlates with a beacon track file.

4) A radar Search message for a radar target that does not correlate (either because the aircraft is not equipped with a transponder or because of a correlation failure).

If correlation failure causes two reports to be issued, they will include one of type (1) or type (2) (without radar radar reinforcement) and one of type (4). PCD reports other than Search messages are always disseminated as received.

The preceding paragraph summarizes the normal dissemination mode of DABS surveillance data. There is an additional mode in which, upon special request, all Search messages are sent to an ATC facility for calibration/registration purposes. In this "all radar data" mode, the full, unfiltered data stream of PCD messages is transmitted independently and in addition to the normal DABS output already described. (Further information pertaining to this mode is included in Section 4.)

2.2 Actions by Control Facility to Use Data

To a degree, the surveillance output of a DABS sensor may be regarded by an ATC facility in the same manner as that of any other sensor; it consists of position measurements (range, azimuth, and altitude) on a set of aircraft. In this sense, the basic data provided by DABS may be used as inputs to tracking computations and for display to controllers in much the same way as at present. The main differences in the basic data are an increase in accuracy (and precision) in the range and azimuth measurements for both DABS and ATCRBS aircraft. It may be desirable to take advantage of this improvement by suitably modifying parameters of the tracking algorithms used, and, perhaps also, of the report-to-track correlation process, which are sensitive to position measurement accuracy.

Above this level of detail, there are significant differences relating to improved DABS aircraft identification and track correlation. These may affect the processing of all beacon reports (ATCRBS as well as DABS), although not of radar (Search) replies reported via DABS. The main areas of processing affected are report selection, track initiation and report-to-track correlation, and controller display. Each of these is treated in the following three subsections.

2.2.1 Report Selection

Enroute ATC facilities presently handle the problem of multiple reports from different interrogators (by using "preferred" and "supplementary" categories based on geographic assignment). In a DABS environment--particularly a partial DABS environment--the task of selection is made somewhat more complicated by the presence of two types of reports from the DABS sensors as well as inputs from ATCRBS interrogators. At the same time, the selection process is aided by information within the DABS messages.

There are three main cases of interest:

1) A DABS-equipped aircraft reported by more than one DABS sensor;

2) An ATCRBS-equipped aircraft reported by more than one DABS sensor (and perhaps by one or more ATCRBS interrogators);

3) A DABS-equipped aircraft reported by DABS sensor(s) and by ATCRBS interrogator(s).

In each case, it is assumed that a track has been established on the aircraft in question and that report-to-track correlation has been accomplished.

For the case of multiple DABS sensor reports on the same DABS aircraft, the ATC facility may choose to operate, as at present, with a fixed selection rule based on geography. Alternatively, the facility may make use of data within the reports to make a more dynamic selection, one which matches the flexibility of the DABS coverage assignment function. This could be accomplished using any or all of four indicator bits in each report; P/S, Mode C, Radar Reinforcement, Radar Substitution, and Data Relay. Selection should tend to favor reports that indicate P/S denoting primary, Mode C* and Radar Reinforcement each designating present, and Radar

*Mode C present implies that the aircraft is in a sensor track state which permits discrete addressing; Mode C not present indicates that the report is based on All-Call replies and therefore the aircraft is still undergoing acquisition.

Substitution and Data Relay denoting not present. (Data which have been relayed may be considered less desirable than local data because of inaccuracy resulting from coordinate conversion.) A possible selection rule that relies heavily on the standard geographic preference is:

1) Use the report from the sensor classified as "preferred," if present.

2) Otherwise, use the report tagged with P/S denoting primary, if present.

3) Otherwise, use the report tagged with Mode C denoting present, if only one report has that tag.

4) Otherwise, use a report tagged with Radar Substitution denoting not present.

Alternatively, a more dynamic selection procedure could be used that omits the fixed preference assignment, i.e., uses the preceding 4-part rule with the first part omitted. This rule might provide more nearly optimized data, particularly for aircraft near DABS coverage boundaries. Some penalty would be paid in processing time to use this type of rule, since report data would have to be extracted before each decision could be made. Conversely, some compensatory saving would result from omitting the map-based determination of "preferred" status. Clearly, other types of selection rules could be implemented, as well as variations on the preceding two rules. No determination of an optimal procedure has been attempted.

The second case is that of an ATCRBS-equipped aircraft reported, in the most general case, by more than one DABS and more than one ATCRBS interrogator. Among the reporting sensors, the fixed preferred/supplementary assignments would presumably be given very much consideration in making a selection, and, indeed, could be used exclusively. The DABS reports, however, could be judged further on the basis of any of several parameters of the reports: Mode C, Mode 3/A, Radar Reinforcement, Radar Substitution, Data Relay, Surveillance File No., Confidence, and Code in Transition. (False Target indication is not included since reports labeled as false should not be selected when another report is available.) Preference in selection should tend to favor the following indicator values: Mode C denoting present, Mode 3/A and Radar Reinforcement each indicating present, Radar Substitution and Data Relay each designating not present, Surveillance File No. indicating nonzero, Confidence indicating high, and Code in Transition designating no.

A selection rule using some of these parameters could utilize a numerical score, giving much importance to the basic preference assignment. In order that the scoring scheme encompass reports from ATCRBS sensors (which lack some of the indicators), both positive and negative scores should be assigned. A hypothetical selection scoring is:

1) +5 points for preferred status, 0 for supplementary

2) +1 point each for Mode C or Mode 3/A = present, 0 for not present

3) 0 for Radar Substitution = not present, -4 for present

4) +2 for Surveillance File No. = nonzero, -2 for zero

5) +1 for Confidence = high, -1 for low

6) +1 for Code in Transition = no, -1 for yes.

The report with the highest associated score would be selected. The particular scores in this example were chosen somewhat arbitrarily, with no attempt at optimization. Obviously, more or less elaborate schemes could be used.

The final case to be considered is that of a DABS-equipped aircraft being reported by both DABS and ATCRBS interrogators. This situation may seem abnormal, since the usual operation of DABS specifies locking out DABS transponders to ATCRBS interrogations. However, it will be common in regions where military interrogators cannot be locked out, and near the boundaries of DABS coverage.

A DABS sensor will unlock transponders to ATCRBS interrogations prior to their leaving a DABS zone into an ATCRBS zone (see Fig. 1) in order that DABS-equipped aircraft will be visible to the ATCRBS sensor. In this way, continuity of surveillance is provided across the boundary. The rule of selecting the reports could be based on proximity, i. e., in regions I and II_a, select sensor A; in regions II_b and III, select B. However, in region II_b it will be desirable to use sensor A for data link service for DABS targets. Because of this consideration, one may wish to make a different choice that favors DABS.

In addition to these geographic considerations, it may be desirable to include also a scoring scheme in the decision algorithm similar to those described above. This option may be needed particularly to cover the case of more than one source of DABS or ATCRBS reports.

The foregoing discussion of report selection assumes that ATC facilities continue to base their surveillance processing on data from a single sensor. If there should be a change to multiple-sensor tracking, the situation becomes quite different. Scoring systems comparable to those shown could then be useful as inputs to a weight assignment scheme for the tracking algorithm.

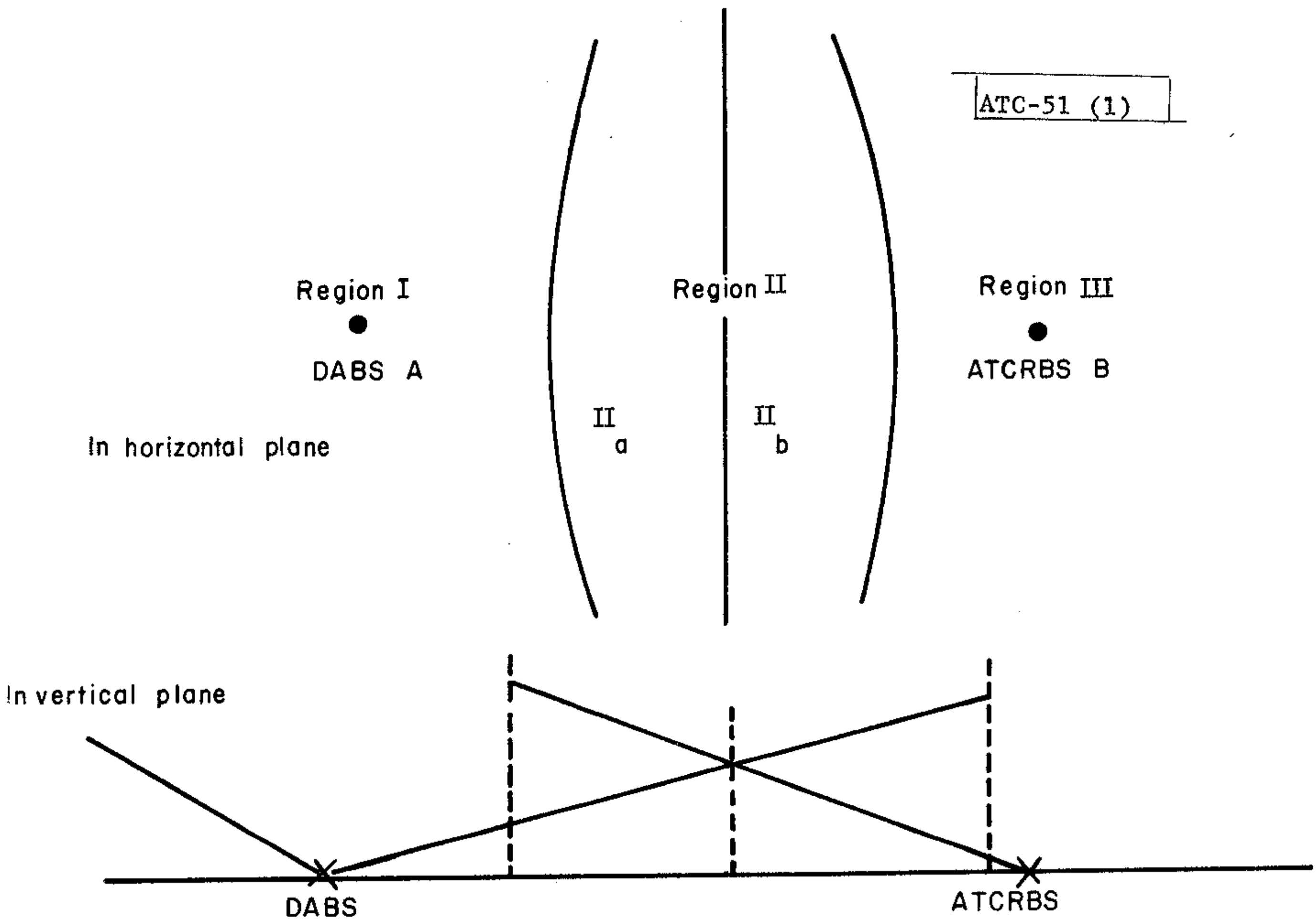

Fig. 1 Coverage in a DABS boundary zone.

2.2.2 Track Initiation and Report-to-Track Correlation

For DABS-equipped aircraft, track identification is easily maintained by means of the unique DABS address. Correlation of DABS reports to each other and to a DABS track file is therefore trivial.

When a new DABS aircraft is reported (one whose address is not present in the files), it will probably be desirable to examine whether or not the report represents a continuation of an existing ATCRBS track. To aid in this kind of correlation, the ATC facility may wish to know the ATCRBS Mode 3/A code for the new aircraft. Since the DABS sensor does not routinely provide Mode 3/A code, the ATC facility would generate a request for the information using the two-way data link. (This kind of communications transaction is described further in Section 3, together with other data link activity that may occur to initialize new aircraft.) The DABS sensor would reply (after its next interrogation) with an ATCRBS ID message. The corresponding ATCRBS track, if any, could then be continued as a DABS track.

For ATCRBS-equipped aircraft, the situation is quite different, but essentially the same as the present-day problem of beacon track initiation and report-to-track correlation. Therefore, the algorithms used could be left unchanged. However, the DABS correlation and tracking of ATRCBS aircraft results in valuable additional information in the form of a Surveillance File Number for all aircraft reports correlating with a track. The use of this number is optional and could range from no use at all to complete reliance on the DABS correlation (i.e., bypassing of the facility's own algorithms). The latter seems unlikely since correlation procedures would have to be maintained in any case for reports from non-DABS sources. The Surveillance File Number would possibly be used in a modified correlation algorithm, in which weight is given in favor of the known DABS correlation. Any use of a Surveillance File Number, of course, implies storing the number in the ATC track files. For the case of multiple reporting DABS sensors, provision would have to be made for storing more than one such number, each with its corresponding source code (DABS sensor ID). The tagging of DABS reports with source code will, in fact, be generally useful for targets of all types.

2.2.3 Controller Display of Surveillance Reports

The surveillance data for aircraft reported by DABS sensors are based on the reports selected as indicated in Section 2.2.1. For ATCRBS reports, the display would presumably show the same information, format, and symbology as currently used by NAS. For DABS aircraft, there are some additional possibilities.

First, it appears to be desirable to distinguish DABS from ATCRBS aircraft on the plan view display. If feasible, special target symbols should be used. The data block will be the same as for ATCRBS, except that

ATCRBS codes (other than emergency codes) will not necessarily be included. An Alert condition or emergency code may cause the data block, or part of it, to be especially emphasized.

Next, it may be desirable to provide for display of supplementary alphanumeric data, preferably at the selection of the controller. This data should probably not be shown on the plan view but on a supplementary display in conjunction with the display of communications messages (see Section 3.3). The information displayed should perhaps include, minimally, the aircraft identification, the data link capability (defined in Section 3), and the ATCRBS ID code (if present).

Finally, the ATC facility software should pay special attention to aircraft identification codes for DABS targets. All displayed information for a DABS aircraft, whether in the data block or in other displays, should be tagged by the voice call sign corresponding to the controller's practice. Information flow between DABS and the ATC facility will identify DABS aircraft by the 24-bit DABS address code, which is an encoded version of the aircraft registration number. For most aircraft, this number is the voice call sign, so that the display software need, at most, perform a recoding of the information. For commercial and some military aircraft, however, it will be necessary to perform conversions between tail number (DABS address) and voice call sign (flight number) [Ref. 3]. The information needed to make the correspondence is included in an "extended data link capability report," which is sent by DABS on request. The request for this information should be generated routinely on all applicable new DABS targets (see Section 3.2.4, Paragraph E). Equivalent information might alternatively be available from flight plans.

3.0 AIR-GROUND COMMUNICATIONS

3.1 Characteristics of Air-Ground Data Link

Communication, by means of the DABS air-ground data link, between an ATC facility and a pilot is actually a process that uses two data links* in succession. In its basic form, the process consists of (1) a message transmitted from the ATC facility to a DABS sensor, (2) processing that message by the DABS sensor computer to set up a ground-to-air message, and (3) transmission of the uplink message. In practice, a complete transaction involves additional transmissions to perform the link protocols, including such functions as pilot acknowledgments.

A communication from a pilot to the ATC facility involves a similar sequence of steps in the opposite order, with an additional step at the

*In this report the two-way data link between a DABS sensor and an ATC facility will be referred to as the "ground link" for brevity. The link between a DABS sensor and a transponder will be referred to as the "air link," comprised of an "uplink" and a "downlink."

beginning to request the use of the air-to-ground channel. This step is necessary because the downlink is under the control of the sensor, not the transponder. The transaction begins when the pilot arranges his message on an input device and pushes a "send" button. This causes a flag to be set (the "B" bit) in every subsequent standard transponder reply. When the sensor reads the B bit, it knows that a message is waiting and schedules an interrogation calling for a long (Comm-B) reply containing the message data. After the Comm-B message has been received, the sensor sends up a signal (CB) in a subsequent interrogation that resets the B bit and indicates to the pilot that the transaction has been completed. This process is referred to as "message extraction."

Each of the data link message transmissions requires the use of a protocol that protects the message against loss and closes the communication loop by notifying the originator when the message has been received or if it cannot be delivered. The detailed message formats and the associated protocols for the air link are presented in Reference 3. For the ground link, comparable material is presented in Reference 1, with a summary of formats in Appendix B of this report.

In the remainder of this section, some general characteristics of message handling are discussed, the information content of every message type is summarized (under the headings of uplink, response to uplink, and downlink messages), and some additional properties of the ground link are given.

3.1.1 DABS Message Routing

In connection with message handling, it is useful to consider IPC as functionally distinct from DABS sensor processing. Thus, IPC acts as an originator and recipient of messages (1) to aircraft, using the collocated DABS sensor and also adjacent sensors, (2) to ATC facilities, and (3) to adjacent IPCs. In this sense, IPC, like ATC, is treated as another external user of DABS communications.

For purposes of delivering messages, DABS sensors normally act independently, even though they may be netted and two or more sensors may be interrogating the same aircraft. Thus, if a sensor receives a message for an aircraft, it will attempt delivery without knowledge of whether or not other sensors are also handling the same message. Also, if a sensor is experiencing difficulty in delivering a message (because of link failure), there is no procedure for handing off the task to another sensor. Communications, unlike surveillance, are handled noncooperatively among sensors except for the data relay mode, as discussed below. This characteristic of the DABS system implies that, for uplink messages, the originator must choose which sensor(s) will handle the delivery. More specifically, the routing should probably be determined by the ATC facility computer, though manual intervention may be desirable.

For pilot-originated messages, the situation is a little different. Multiple sensors could not be permitted to handle such messages freely without risking the loss of messages under some circumstances. Therefore, the "primary/secondary" assignment scheme is used to prevent more than one sensor from attempting extraction of a pilot message. There is still no direct cooperation between sensors in handling such a message; however, in case of a persistent link failure, there is provision for handing off the "primary" designation to a second sensor, at which time the original "primary" becomes "secondary". With the acceptance of primary status, the sensor is then responsible for attempting message extraction.

Care is taken that the data link is protected in the management of primary/secondary assignments, i.e., simultaneous dual primary assignment (which could cause undetected loss of a pilot message) is strictly avoided. Situations in which no sensor acts as primary (which could cause delivery delay) cannot be totally avoided, but will only occur as brief transients if a second sensor has coverage of the aircraft. If an aircraft crosses a boundary that triggers hand-off of the primary assignment, such hand-off is inhibited until any pilot-originated downlink transaction in progress is completed.

The DABS sensor receiving a downlink message has responsibility for routing the resulting output on the available ground links. When the downlink is a specific response to a particular ATC facility input, the message will be directed to only that user. When the downlink is pilot-originated, the DABS sensor will disseminate the output, following the same dissemination map that is used for surveillance data outputs.

Additional procedures apply to a sensor operating in the data relay mode (see 2.1.2 for a definition of this mode). As with surveillance reports, the operation of the data relay mode for uplink messages depends on the preselection of a DABS sensor as a relayer with respect to a particular unconnected sensor/ATC pair, and on the aircraft in question being in a coasted track state maintained by track data from the unconnected sensor. If a message is to be relayed to an unconnected sensor, part of the procedure of the relaying sensor is to prefix the message with the sender ID code (of the originating ATC facility), so that the receiving sensor will know where to direct any response messages. The decision of whether to relay a particular message and what other procedures the relaying sensor should use are a function of message type and priority. The rules are given below for each message type in Section 3.1.3 and 3.1.4. All sensor response messages (3.1.4) and downlink messages (3.1.5) which are received from an unconnected sensor and addressed to an unconnected ATC are always relayed.

3.1.2 Data Delays

An uplink message received at a DABS sensor undergoes processing by several software routines before it is available for transmission to an aircraft. The resulting delay in delivery depends not only on the time required to execute processing but more particularly on rates at which tasks are performed (the reading of input buffers and the cycling of software routines). For the engineering development version of DABS sensors, an upper limit of 1/8 of an antenna scan period is specified for the total duration of such delays. For a 4-sec rotating antenna, the worst case of processing delay that could result would be 0.5 sec. Downlink messages have a corresponding maximum processing delay specified as 3/32 of a scan period, or 0.375 sec for a 4-sec rotator.

These processing delays are, of course, only one component of the total time that may elapse between the initiation of a message and its receipt. The entire chain of delays may include, for an uplink message: (1) processing within the ATC computer, (2) processing and waiting time at the ground link transmission interface, (3) ground link transit time including possible delays for "reject" replies and subsequent retransmissions in cases of link difficulties, (4) processing time at the DABS ground link receive interface, (5) DABS software processing delays, (6) waiting time for antenna to reach aircraft azimuth, and (7) uplink transit time including possible delays for retransmissions in cases of link difficulties. Item 6 is never larger than one antenna scan period, and is equal to 1/2 scan period on the average, since message initiation times are uncorrelated with aircraft beam positions. Item 7 may be substantial if a link fade extends over an entire beam dwell period. For downlink messages, the delays occur in reverse order but are comparable. In some cases, there will be an additional 1-scan delay between transmission of a pilot's "send" request and the subsequent extraction of his message. However, both of these downlink transmissions may occur within the same beam dwell (except for downlink Extended Length Message (ELMs), which always require at least a second scan). Messages handled under the Data Relay mode undergo additional delays for processing by the relaying sensor and for transmission on the sensor-to-sensor link.

Uplink messages are characterized by a simple system of priority handling, which has some bearing on delivery service. Such messages (other than ELMs) carry an explicit 1-bit tag representing either "high" or "standard" priority. The tag is supplied by the message originator, either by manual input or automatically by his input device or message processor. In the absence of this tag, the default value "standard" is assumed by DABS. The priority classes are fixed, rather than time-varying, and ELMs are implicitly assigned to a third priority class below "standard." Priority level does not affect handling of a message on the ground link or in most of the DABS processing. It does affect the order of message delivery on the uplink, but the effect will only be noticeable in cases of heavy queueing of messages to a given aircraft or of a large total number of transactions involving aircraft within a beamwidth. In such cases of heavy link loading, a low priority assignment would increase the probability that transmission of the message is delayed until the next scan.

Somewhat related to the question of delivery delays is the uplink message parameter "expiration time," which is a user supplied input similar to priority, with a standard default value supplied by DABS. It defines the number of scans during which a DABS sensor will continue to attempt delivery of the message. The value of expiration time, therefore, should be chosen to express the useful lifetime of the message. If a prolonged link failure should result in a message expiring before delivery, the sender is notified of that fact. (Notification of successful delivery is also sent as soon as it is known.) The expiration time is thus the approximate maximum time during which the sender of a message may be in doubt regarding its successful delivery; in this sense it represents an upper bound to the range of possible data delay times.

3.1.3 Uplink Messages

Among the messages that are defined for the link from an ATC facility to a DABS sensor, six specific types are classified as "uplink messages." Each of these messages carries a distinctive 8-bit type code, and the full format for each is given in Appendix B. The information content as well as the DABS sensor handling of each type are characterized in the following paragraphs.

A. Tactical Uplink. This is the basic message for transmitting information from ATC to a pilot. Each tactical uplink message transmitted on the ground link causes a DABS sensor to dispatch from one to four Comm-A uplink transmissions to a particular DABS-equipped aircraft. Each Comm-A transmission, which corresponds to a "segment" of the full message, will be delivered strictly in the order in which it is input. The tactical uplink format includes a DABS Address to identify the intended aircraft, a message number (MSG No.) to permit references to the uplink message in DABS response messages,expiration time and priority (EXP, P) as discussed in Section 3.1.2, segment count (SC), and message text (MA), which contains the actual data to be sent on the uplink. The MA field is repeated as many times as indicated by the contents of the SC field. Each MA field consists of 56 bits, which are not interpreted by the DABS sensor but are used intact as the MA field of the Comm-A interrogation format [Ref. 3]. Coding for this field must satisfy the requirements of the particular output device for which the message is intended and of the "standard message interface" associated with the DABS transponder [Ref. 4]. These requirements specify certain control bits at the beginning of the MA field, including a pilot acknowledgment request bit (AR), and (minimally) an output device address code (MDES). If the device is capable of displaying a multisegment message, further data fields are needed within MA to address a particular segment of the display and otherwise control its operation. An example of a device of this type is the 16-character "ATC message display" specified as part of the DABS engineering development model procurement [Ref. 5].

When a tactical uplink message is received at a DABS sensor, the handling procedure begins with acceptance testing (described in Section 3.1.4) and then, if the message is accepted, a Comm-A transaction is generated for each segment. Short transactions (surveillance interrogations) already listed for the aircraft will be lengthened to become Comm-A(s); additional new transactions are generated as required. The delivery sequence is fixed by the original order of the MA fields since no new transaction is attempted until the preceding one has succeeded. If the tactical uplink message is addressed to an aircraft for which the data relay mode applies, it is relayed to the unconnected sensor for uplink delivery. Further, if the priority of the message is "high", the relaying sensor also attempts uplink delivery; if priority is "standard", only relayed delivery will take place. Further processing of tactical uplink messages to provide a user response is described in Section 3.1.4.

B. ELM Uplink. This message type is used for longer messages, perhaps for use with teletype-like output devices rather than special purpose displays. The protocol associated with ELMs is intended to make more efficient use of the air-ground channel than is possible with standard (Comm-A and Comm-B) transmissions, which require two-way transmissions for each segment. The ELM Uplink format includes DABS address, message number, and expiration time defined as for tactical uplink. The remainder of the message is a "length" parameter, which is a segment counter with a maximum value of 16 segments, and an ELM test field. The ELM text is variable in length in multiples of 80 bits, with a maximum of 1280 (16 x 80). If longer messages were to be sent, they would have to be subdivided and would be treated by DABS as independent ELMs.

The ELM text field is not interpreted by the DABS sensor but is used intact in a sequence of Comm-C uplink transmissions. Coding for this field must satisfy the requirements of an ELM output device (not specified at present): there are no additional requirements imposed by the DABS transponder or its data link.

DABS processing of ELM Uplink messages is comparable to that of tactical uplinks. One difference is that the entire message will normally be set up as a single transaction, eliciting only one reply to all segments. Since any segment may fail to be delivered, there is provision for retransmission of only those segments. This procedure implies that the order in which segments are received at the output device is not predictable. Since the segments are explicitly numbered (by the DABS sensor processing), there is no difficulty caused by this. Further details of ELM delivery protocol are given in References 3 and 6. ELM Uplink messages are never relayed even if the data relay mode applies (because of their low priority and considerable length).

C. Request for Downlink Data. This message is used to obtain a readout from a device on a DABS-equipped aircraft, using the air-to-ground Comm-B transmission. The format contains several fields identical with tactical uplink data fields (DABS Address, message number, EXP and P), and an additional one: the 4-bit device address (MSRC). The handling of this message by a DABS sensor consists of acceptance testing (see Section 3.1.4) followed by setting up a transaction to extract the desired information via the downlink. If a transaction is already waiting that consists of a standard unsynchronized interrogation with a short reply, this transaction is modified to handle the downlink request by changing the reply length to "long" (RL = 1) and copying the MSRC field. If not, an additional interrogation is scheduled for this purpose. If the data relay mode applies, messages of this type are always relayed, according to the same rules as for Tactical Uplink (with priority "high" or "standard"). Further processing of the received reply is summarized in Section 3.1.5.

D. ATCRBS ID Request. Since DABS transponders incorporate an ATCRBS capability, provision is included to read out the Mode 3/A code via the DABS link. The ID request is logically similar to a request for downlink data, except that the Comm-B downlink is not required. Instead, the standard reply transmission format (short or long) may include the Mode 3/A code in place of altitude. The ATCRBS ID request format comprises simply a DABS address and message number; no other parameters are needed. Handling of the ID request by a DABS sensor consists of acceptance testing and setting up the desired transaction. If a transaction is already waiting that calls for a standard unsynchronized reply with altitude, it will be modified to extract the Mode 3/A code (by setting AI = 1 in the interrogation), provided that altitude is already available from an earlier transaction within the same scan. Otherwise, a new surveillance transaction is set up with AI = 1. If the data relay mode applies, an ATCRBS ID request will be relayed and local delivery will also be attempted. Handling of the reply data is described in Section 3.1.5. (It should be noted that, without waiting for a request, a DABS sensor will routinely ask for a Mode 3/A reply from any newly acquired DABS-equipped aircraft.)

E. Message Cancellation Request. Strictly speaking, this is not an uplink message. However, it is a request to cancel the delivery of an uplink message and consequently is included here. Two types of uplink messages are subject to cancellation requests: tactical and ELM. The other types do not result in a display of data to the pilot; hence, it is not necessary to provide for cancellation. The format contains the usual fields for DABS address and message number, and the referenced message number and type code that identify the message to be cancelled. (Referenced type code is not basic but is required for convenience in processing.) DABS sensor handling consists of acceptance testing and then deleting the message from the files in which it may be present. Of course, the cancellation may fail because delivery has already taken place. If the message to be cancelled has multiple segments (whether tactical or ELM), all segments will be deleted even though some of them may have already been delivered. Following the attempt to delete, there is no further specific response to the cancellation request. Thus, if the cancellation is successful, the ATC facility will hear nothing further concerning the original message. If unsuccessful, the ATC facility will receive the usual response to the original message. In either case, there is no reply to the cancellation message itself. If the data relay mode applies, this type of message will be relayed and local delivery attempted also.

F. Data Link Capability Request. This message is a request for the 6-bit data field "data link capability," which identifies, as far as possible, the configuration of output and input devices associated with a particular DABS transponder. The message format contains no parameters other than the DABS address. Obviously, the capability information is needed by an ATC facility before it attempts sending uplink messages to the aircraft. A DABS sensor fundamentally obtains this information from an all-call reply, and maintains it in the surveillance file. If it acquires a new aircraft by handoff from an adjacent sensor rather than by all-call, the capability information is passed on along with the track. Thus, receipt of this request message does not trigger any particular uplink transmissions. Instead, the desired information is simply retrieved from the surveillance file and the appropriate output message is generated and transmitted to the requesting facility. Since the appropriate response is available locally, this type of message is never relayed under the data relay mode.

3.1.4 Sensor Response Messages

Sensor responses to uplink messages do not strictly fall under the heading of ATC/aircraft communications, since they do not directly make use of the air link. However, they are an important part of the uplink message delivery protocol. Response messages are generated by the DABS sensor as part of two distinct processes that take place sequentially following receipt of an uplink message. The first process is acceptance testing, which determines the deliverability of each uplink message of whatever type. The second process is that of technical acknowledgment, and it is carried out after uplink transmission on either of two uplink message types (tactical and ELM), provided that they have passed the acceptance test. There are two types of response messages, and they correspond exactly to the two processes.

A. Message Rejection/Delay Notice. Acceptance testing of each uplink message consists of a search of the DABS sensor surveillance file for the aircraft addressed and a test on the track state of that aircraft. There are five possible outcomes to the acceptance testing:

1) Rejection: If the aircraft addressed is not listed in the surveillance file, the message is not deliverable, and a rejection/delay notice is generated that indicates "rejection".

2) Delay: If the aircraft is listed but is in a state of low track quality, a notice is generated that indicates "delay". Low track quality includes acquisition states in which the track is not yet fully established, as well as coast states in which link failure is being experienced. In the latter case, the track may be maintained with the use of external data; however, the case in which the data relay mode applies is not included here.

3) Data relay, with local delivery: If the data relay mode applies and the message is one of those types listed in 3.1.3 for which local delivery is attempted in addition to relaying, a notice is generated that indicates "relayed delivery being attempted (delay)". This type of notice conditions the ATC facility to expect further responses from both sensors.

4) Data relay, without local delivery: If the data relay mode applies but the message is one of those types for which local delivery is not attempted, no rejection/delay notice is generated. Responses will be generated in the usual way by the unconnected sensor.

5) Acceptance: If the aircraft is listed in full track state, no notice of this type is issued.

Thus, acceptance testing results in an output in only the exceptional case of difficulty in deliverability. Following issuance of a rejection notice, the referenced message is deleted. Following a delay notice, the message is handled as if there had been full acceptance, but with the expectation of a delay in delivery.

The message format contains three data fields: the usual DABS address, the referenced message number, and the "qualifier," which may take on any of three values, "rejection", "delay", and "relayed delivery being attempted (delay)".* It should be noted that message numbers (and hence referenced message numbers) have four bits, which permit the unambiguous handling of as many as 16 simultaneous uplink message transactions of all types to a single aircraft.

B. Message Delivery Notice. When a tactical uplink message segment is delivered by means of a Comm-A transmission, the received

*"Relayed delivery being attempted (delay)" is encoded as a binary "10". This supersedes the definition "10 = not used" in Ref. [1].

transponder reply constitutes a technical acknowledgment of the receipt of that segment. For segments of ELM uplink messages, the procedure is more elaborate but similarly results in technical acknowledgments specific to each segment. Whenever all segments of an uplink message (either tactical or ELM) have been acknowledged in this manner, the DABS sensor generates a message delivery notice for the originator that indicates successful delivery. If any segment is not acknowledged on the downlink, the sensor will continue to attempt delivery until the expiration time of the message is reached. If all or part of the message remains undelivered at expiration, a delivery notice is generated that indicates failure. In this way, each tactical or ELM uplink that has not been rejected as undeliverable is sent as soon as success or failure has been determined. Delivery notices are not used in the cases of a request for downlink data or the ATCRBS ID request because each of those types results in a specific downlink reply when successfully delivered.

The delivery notice format is comprised of three data fields: DABS address, referenced message number, and delivery indicator (DI). The latter is a two-valued parameter with values indicating "message successfully delivered" and "message expired undelivered."

3.1.5 Downlink Messages

Among the messages that are defined for the ground link from DABS to ATC, five specific types are classed as "downlink messages." As with uplink messages, each of these messages carries a unique type code and has a format included in Appendix B. Downlink messages are generated by the DABS sensor as a result of information received via the DABS downlink. Such information may originate with the pilot or it may result directly from a previous uplink message. Each of the five types is characterized in the following paragraphs.

A. Tactical Downlink. A tactical downlink message is generated whenever a DABS sensor receives a Comm-B reply. As presently defined, a tactical downlink message is comprised of a single segment of data; consequently, if an airborne device is used that generates more than one Comm-B segment, separate independent messages will result. The tactical message generated will be routed to either: (1) all ATC facilities receiving DABS surveillance data on the aircraft if the Comm-B was extracted at the request of the pilot, or (2) the specific ATC facility that has need of the information if the Comm-B resulted from an earlier request for downlink data transmitted by an ATC facility. No other actions are taken by the DABS sensor, except to send up a resetting signal (CB) in the case of a pilot-originated Comm-B. (This serves to free the channel for any subsequent pilot "send" request and to indicate technical acknowledgment.) There is no limit to the number of ground-requested Comm-Bs; but only one pilot-initiated transaction for a given aircraft may be pending at one time, and only the DABS sensor designated "primary" will handle it.

The downlink message format is comprized of two fields: The DABS address of the sending aircraft and the 56-bit message data (MB), which is copied directly from the Comm-B reply. Any desired control data, such as input device ID, must be coded into the MB field. The MB field is not interpreted by the DABS sensor.

B. ELM Downlink. This type of message closely resembles its uplink counterpart in function and structure. It is always pilot originated; as with tactical downlinks, only one such message at a time can be in process from a given aircraft and only the DABS primary sensor for that aircraft will attempt to extract it. The message corresponds to a sequence of special (Comm-D) replies, each containing one segment of data.

The message format consists of three data fields: The DABS address of the sending aircraft, the "length" parameter specifying the number of segments in the message, and the ELM text, which is variable in length in multiples of 80 bits to a maximum of 1280. The text field is assembled by copying the MD fields of the Comm-D replies in this proper sequence. These fields are not interpreted by the DABS sensor.

C. Pilot Acknowledgment. There are two modes available in DABS for handling pilot acknowledgments to tactical uplink messages. In one mode, pilot response buttons are an integral part of the uplink display device, and their use triggers a request to send a Comm-B downlink that contains the pilot response data. When received at the DABS sensor, this downlink reply generates a tactical downlink message output that the sensor does not distinguish from any other pilot-originated tactical downlink. At least one planned device for ATC uplink messages will handle acknowledgments in this manner [Ref. 5]. (Pilot responses, if any, to ELM uplink messages will similarly make use of the ELM downlinks.) Responses handled in this mode are of no further concern here.

The other mode provides a method for transmitting pilot acknowledgments from transponders that may not have an associated Comm-B capability. This mode is available in all DABS transponders. Its use is presently planned for an IPC/PWI display; it is not clear whether or not any ATC message output devices will also make use of it. In this mode, the pilot response data are transmitted in a data field (PBUT) present in every standard DABS reply, long or short. Any DABS sensor receiving a reply with PBUT will react to it, whether or not the sensor is designated primary for that aircraft. The sensor response consists of transmitting a resetting signal (CP) to the transponder and generating a downlink message of the type "pilot acknowledgment." This message contains two data fields: DABS address and PBUT, which takes on the two values "will comply" and "cannot comply." The message is sent, as other pilot-originated messages, to all ATC facilities that are receiving surveillance reports on the aircraft. Note that the message contents, as well as their routing, are nonspecific, i. e., the message being acknowledged is not explicitly referenced, nor is the cockpit display device identified.

D. ATCRBS ID Code. This message is generated whenever a DABS sensor receives a reply from a DABS transponder containing Mode 3/A code. Such a reply may occur for any of several reasons: (1) an ATCRBS ID code request is received from a system user, (2) the pilot has pushed his "alert" button indicating his wish to have his code read out, (3) the pilot has dialed an emergency code 7600 or 7700, or (4) the aircraft has been newly acquired by the DABS sensor. If the reply with code results from a code request message from a single facility, the resulting output message is transmitted to only that user. In all other cases, the ATCRBS ID code message is transmitted to all facilities receiving surveillance reports on the particular aircraft. The message format contains only the DABS address and the 12-bit Mode 3/A code.

E. Data Link Capability. This message is used to report the 6-bit capability field received in all-call replies. It is generated either (1) when a new DABS aircraft is acquired, or (2) when requested by an ATC facility by means of a data link capability request message. In the latter case, the message is transmitted to only the requesting ATC facility; in the former case, to all facilities receiving surveillance reports. The message format simply contains the DABS address and the capability field.

3.1.6 Ground Link Protocol

Messages between DABS sensors and ATC facilities will conform to the protocol and formats of the Common ICAO Data Interchange Network (CIDIN) for a balanced point-to-point configuration [Ref. 1]. In order to place in context the description of ground link messages (in Sections 3.1.3 to 3.1.5), the principal characteristics of the CIDIN link protocol are briefly summarized here.

Ground link messages correspond to CIDIN "frames." The message data, which has been described as if it were the entire message, is the "link data field" within the frame. The rest of the frame is comprised of control fields including: beginning and end flags, station address, frame sequence number, command code, and frame check sequence (a parity code that protects the entire frame excluding flags). There are six command code values defining various types of frames. The basic data message is of the command type "exchange" (X). After receiving an X frame, the receiving station will reply with one of three types of response frames: "accept" (A) if the X frame is satisfactory, "reject" (N_1) if a parity error is detected, or "reject" (N_2) if some other error regarding format is found. A reject response causes retransmission of the original X command. If no response is received during a time-out period, the sending station sends an "enquire" (E) command, again requesting a response. Finally, there is a "reset" (R) command that causes the receiving station to re-initialize its frame sequence numbering, which otherwise advances serially.

The purpose of this protocol is to help provide confidence and reliability in the ground link operation. None of the protocol operation, other than parity encoding and error detection, involves the link data field contents (message data). The protocol operation (including formatting of frames) is achieved by special interface hardware at each end of the link. Logically, it may be thought of as operating outside the data processors of the DABS sensor and the ATC facility, even though in implementation it could share the use of these processors. In this sense, the entire CIDIN protocol is transparent to the sensor/ATC facility message processing previously described.

These considerations apply not only to the air-ground communications designated in Section 3, but also to the other ground-link communications designated in Section 4. In the remainder of this report, CIDIN protocol considerations will not be mentioned again, and "messages" on the ground link will by synonymous to the "link data fields."

3.2 Actions by Control Facility to Use Air-Ground Data Link

This section consists of: (1) general considerations relating to message handling capability in an ATC facility, (2) actions involved specifically in the generation of messages to pilots, and (3) actions relating to the interpretation of air-to-ground messages.

The incorporation of an air-ground data link capability raises many questions regarding the operational procedures of an ATC facility and resulting system design modifications. With the aid of information that will be gained from DABS testing at NAFEC, these issues should be addressed as part of the planning for implementing DABS and its integration with NAS.

3.2.1 Message Handling Capability

In order to make use of the DABS data link, an ATC facility will need to add certain kinds of capability, both hardware and software. There is no attempt here to state design or modification requirements, but only to suggest some functional areas that are involved in message handling. Some of the capability described may already exist or be easily achievable; other parts may involve substantial modification to existing equipment.

A. Ground Link Interface. Processing hardware (and software) is needed for both the receive and transmit channels to perform message formatting and carry out the protocol summarized in Section 3.1.6

B. Uplink Message Processing. The main software task to be performed for an uplink message is to select the appropriate DABS sensor (or sensors) by which the message will be transmitted. This can be achieved by providing access for the message handling routines to the facility's surveillance data file where the identities of currently reporting DABS sensors and their primary/secondary status are stored for each aircraft. Following this selection, the message is routed to the appropriate output port or buffer. There may be other subsidiary tasks as well, such as message reformatting, character code conversions, and translating the aircraft flight number into the standard DABS address (in cases where these differ).

C. Downlink (and Response to Uplink) Message Processing. For all incoming messages, the main task in software is routing the message to the appropriate output terminal or memory location. This is accomplished with the aid of surveillance file information that can be used to correlate the message with an aircraft position and, hence, with a particular controller station. Message data, such as type code, may be useful to specify a particular output device. For response to uplink messages, it will be necessary to make the association with the referenced message and act accordingly. Subsidiary tasks may involve code conversions, message reformatting, and DABS address conversion.

D. Internal Communication Lines. These lines are needed to transmit messages between the message processing equipment and various I/O stations.

E. I/O Devices. These devices should be capable of displaying uplink messages as they are originated and at least for the duration of the transaction that they trigger. Related response messages and pilot acknowledgments should be displayed in a manner that the status of the uplink message is always visible. Message status display could include internal as well as DABS-supplied parameters. For example, a sequence of displayed status values could include symbols that indicate:

1) Transmission pending
2) Awaiting ground link transmission
3) Awaiting uplink transmission
4) Uplink technical acknowledgment received
5) Awaiting pilot response
6) Pilot wilco received

Downlink messages should be displayed in a manner such that they may be read in the context of any current uplink messages involving the same aircraft. The message display should also make available (perhaps at operator request) other information, such as data link capability, relating to the aircraft. It may be desirable to integrate the message device with the display of flight plan information.

3.2.2 Uplink Message Generation

The general actions involved in producing uplink messages are directly implied by the material in Section 3.1.3 and 3.2.1. Note that the presence of a possible data relay mode does not affect the ATC generation of uplink messages. A few additional points should be made regarding specific message types.

A. Tactical Uplink Message. To produce a tactical uplink message, the originator must of course supply the requisite data: DABS aircraft ID and message text, including segment count. Expiration time and priority are optional, and the message number will be supplied by the processing equipment. One additional optional parameter may be useful. For maximum speed and reliability, it may be desirable to transmit urgent messages via all available DABS sensors. This may be accomplished by tagging the message with a priority designation that indicates such "multilink" handling. This designation would not become part of the link data field but would be appropriately interpreted by the message routing software within the ATC facility processor. Multiple copies of the message would then be sent out over the links to the different DABS sensors. When multilink delivery is not specified, the message would be routed to the DABS primary sensor.

B. ELM Uplinks. For ELM uplinks, the requirements are similar, except that there is no settable priority and no option of multilink delivery.

C. Request for Downlink Data. A request for downlink data simply requires setting the data fields DABS address and downlink device code. Of course, knowledge that a particular aircraft is equipped with the specified device is assumed (see Section 3.2.4, subsection E, data link capability message). Expiration time and priority are optionally settable, as with tactical uplinks. Multilink delivery of the request (and, as a result, of the downlink reply) is also optionally available if implementation of this feature is desired.

D. ATCRBS ID Request. An ATCRBS ID request requires no inputs other than DABS aircraft identification. In practice, it may be useful to have this message generated automatically by the surveillance processing software whenever a new DABS aircraft is reported and the ATCRBS code is not received promptly. In this way it would be possible to facilitate the association between an existing ATCRBS track and a new DABS track, rather than carrying them both. Alternatively, more stringent criteria for issuing the message could be adopted, in which proximity to an ATCRBS track or geographical coverage parameters are brought in.

E. Message Cancellation Request. A message cancellation request, regarding an earlier tactical or ELM uplink message, may be issued at any time before a message delivery notice has been received. There are two hypothetical situations in which it may be considered desirable to issue a cancellation. First, the earlier message may be found to be in error or it may be desirable to supersede it; it may be considered important to minimize the chance that the pilot will see the undesired message. Second, if a message has been transmitted in the multilink mode and a successful message delivery notice has been received from one DABS sensor, it may be desirable to minimize redundant delivery by canceling the remaining sensors. (In this second case, the cancellation message could be generated automatically by the software as part of the delivery notice processing.) Since successful cancellation can never be guaranteed, the question of implementing a cancellation message capability at an ATC facility should be examined.

F. Data Link Capability Request. A data link capability request will be issued once, at most, when a new DABS aircraft is reported. When the DABS aircraft is first acquired by a DABS sensor, the sensor will disseminate a data link capability message; consequently, a request for this information is not generally needed. However, there may be circumstances in which an ATC facility begins receiving surveillance reports on a DABS aircraft, and the capability data have never been received or have not been retained in storage. To meet this case the capability request is needed, and it should be generated automatically in software as needed on new DABS aircraft.

3.2.3 Sensor Response Message Interpretation

In general, the handling of sensor response messages is straightforward and results in a status output to the originator of the referenced message. In all cases, it is first necessary to make an association in software between the response message and the referenced message. If multilink delivery of an uplink message is involved, then the processor of responses must expect multiple sets of responses. This situation includes the case of data relay mode with local delivery attempted, as noted in 3.1.3 and 3.1.4.

A. Message Rejection Notice. For a message rejection notice, it may be desirable to react in software by re-issuing the message to another DABS sensor, if any is available. This notice is essentially an error flag since it states that a DABS sensor currently reporting surveillance data (and perhaps designated primary) has no file on the aircraft addressed. For a message delay, including the data relay case, no action is required. Optionally, the "delay" tag may be displayed to the originator so that he may re-initiate the message using multilink delivery. An alternative option would be to re-initiate the message automatically in software if another sensor is available. Either option could be reserved for high-priority messages only.

B. Message Delivery Notice. A message delivery notice indicating successful delivery should be displayed to the originator. Further, for the case where the referenced message did not request pilot response, the original transaction could be deleted from software. A delivery notice indicating failure should also be displayed, and could optionally trigger re-initiation via another sensor. Because time will have expired on the referenced message, it will probably be preferable to have re-initiation occur only by action of the originator rather than automatically.

3.2.4 Downlink Message Interpretation

The general actions involved in the handling of downlink messages have been described. Routing is the principal task; pilot-originated messages are routed to the appropriate controller station, and messages that result from an earlier uplink message are transmitted to the output device or internal function that originated the request. Specific comments follow.

A. Since the data portion of a tactical downlink message consists of only DABS address and MB (text) fields, it will be necessary for the processing software to interpret the MB data to read the source device code. If this matches the device address code (MDES) in a pending request for downlink (or in a tactical uplink requesting pilot response via the Comm-B channel) that had been made to the same aircraft, the association has been made. The downlink message can then be routed appropriately and the pending request deleted. If there is no match on MDES or no pending request, the downlink message is assumed to be pilot-originated.

B. Probable uses for the ELM link are largely undetermined at this time. It may be that all downlink ELMs are pilot-originated messages intended for output devices associated with controller stations. In this case, routing of the message is trivial. If there are other types of ELM users, then routing and any other actions would have to be based on control data within the ELM text field. Such control data are presently undefined.

C. To accomplish the proper handling of pilot acknowledgment messages, it is necessary initially to store, with a pending tactical uplink message, the fact that a pilot acknowledgment has been requested, and whether or not the pilot response will be via the PBUT or the Comm-B channel. (See section 3.1.5 for this distinction.) A pilot response using Comm-B is received in the same manner as any other pilot-originated tactical downlink message, but may then be associated with the pending uplink and routed appropriately. A response via PBUT (the only type that produces a pilot response message) contains no specific references. It may be associated with a pending request for pilot response via PBUT and handled accordingly. If no such association is found, it may be assumed that the pilot response actually refers to someone else's uplink message, presumably from IPC. In that case, the pilot response message may be ignored. There is a possible ambiguity if both ATC and IPC attempt to use PBUT in the same aircraft at approximately the same time. The occurrence of this problem may be minimized by communications directly between IPC and the ATC facility. The problem does not arise at all if ATC facilities avoid addressing cockpit devices that make use of the PBUT channel.

D. ATCRBS ID Code messages are primarily the concern of the facility's surveillance processor, as an aid in report-to-track correlation. If desired, the code value may be made available for output on the controller's plan view display or otherwise. If the code has an emergency value, it should, of course, be displayed appropriately. Received messages of this type should also be checked against any pending ATCRBS ID code request; if an association is made, the request may then be deleted.

E. A data link capability message may require considerable handling, depending on the facility's previous knowledge of that aircraft's capability and the actual value of the capability data. If the message refers to an aircraft not on file, or if capability data for that aircraft is already stored, the message can be ignored (though in the latter case it may be advisable to compare the stored capability value with the new value in case of an error). If the data are new and refer to an aircraft of interest, then they must be interpreted by standard code conversion or table lookup as defining a set of MDES/MSRC codes that are addressable on that aircraft. These codes are than stored and made available to all appropriate message input devices as part of the aircraft status or data link display. The specific coding of the 6-bit capability field is not fully defined at present. It is expected, however, that five of the bits will be reserved to signify the presence of or absence of five particular cockpit devices. For some elaborately equipped aircraft, it is expected that these five bits will be inadequate to fully define data link capability. The set of such aircraft is expected to consist, more or less, of the commercial carriers (the aircraft that use variable flight numbers). In order to permit communication of both the full data link capability and the flight number, the sixth bit of the capability field is defined as an indicator of "extended capability." If this bit is set in a received capability message, the facility software should initiate a transaction to extract extended capability information. The transaction is a request for downlink data message with the particular device address code MSRC = 0001. The resulting tactical downlink message will contain in its MB field the desired available device codes and the variable flight number. The device code data should be stored and displayed together with the basic capability data previously received, and the variable flight number (if any) should be appropriately stored. The latter is important since it enables the facility to associate the DABS address for that aircraft with the flight number (for those aircraft whose voice call sign is the variable flight number rather than the aircraft tail number). Such an association may also be made using flight plan information, provided that DABS address is part of a standard flight plan. In that case, use of the DABS-provided information could serve for verification.

A comment may be worthwhile on the consequences of an error in device address code information. If for any reason a tactical uplink message not requesting pilot acknowledgment or device response is transmitted to an aircraft that does not have the particular device addressed, the MA data will "die" unnoticed on the link between the transponder and the attached cockpit devices. In the meantime, however, the transponder will have replied normally, not detecting any error condition. This would result in a message delivery notice back to the sender, indicating successful delivery. In other words, DABS does not protect against this kind of situation, and an undetected error results.

4.0 DABS SENSOR/ATC FACILITY CONTROL INTERACTIONS

Section 3 of this report has covered exchanges of information between ATC facilities and pilots via the DABS data link. This section is concerned with a variety of types of interactions between ATC facilities and DABS sensors themselves. For the most part, these interactions provide information that one station needs to know from the other in order to function properly. The emphasis is on the reporting and testing of operational status. To some extent, the messages involved here do not fit perfectly into larger categories but do have significant individual roles.

With the exception of operational IPC interactions (Section 4. 1. 1), the interactions described here do not directly deal with the control of individual aircraft, and hence are not primarily the concern of controllers. Rather, they support a management function within ATC, which is concerned with the proper operation and maintenance of DABS sensors.

The nature of any control interaction between an ATC facility and a DABS sensor which form an "unconnected" pair (as defined for the data relay mode) is unclear. It would seem that the unconnected sensor would rely primarily for management and maintenance functions on some other ATC facility to which it is directly linked. Nevertheless, relaying of some messages involved in control interactions is provided for. The rules governing the selection of messages to be relayed are as follows:

1) All messages from the unconnected sensor addressed to the unconnected sensor are to relayed. (This is the same rule as for sensor-to-ATC messages treated in Section 3.)

2) Messages from the unconnected ATC are not to be relayed, except for the following types: altimeter correction and NAS failure/recovery (see Section 4. 2. 2, Items C and D).

3) The messages indicated above to be relayed shall always be relayed whenever the site adaptation has been made which designates the appropriate data relay configuration. This rule holds whether or not the relay mode is in effect for any aircraft.

All of the messages discussed below make use of the same ground link as described previously. The message formats are, as before, actually just the "link data field" portion of ground link messages. The ground link protocol of Section 3.1.6 applies in its entirety, as do the related aspects of message handling described in Section 3.2.1.

4.1 IPC-Related Interactions

Intermittent Positive Control (IPC) is an automated function associated with DABS sensors that can detect conflicts among aircraft and issue advisories and avoidance maneuver commands to DABS/IPC-equipped aircraft via the DABS uplink. Its maneuver commands are issued preferentially for VFR aircraft. Since one or more IFR aircraft may be in a conflict situation that is being handled by IPC, it is important that the outputs of IPC be available to the controller. This interaction is further described in Section 4.1.1. In addition, there is an administrative and legal requirement for recording IPC messages at ATC facilities (see Section 4.1.2).

4.1.1 IPC Operational Messages

While IPC operation is functionally distinct from that of DABS, it is collocated with DABS sensors. As presently defined [Ref. 7], the IPC processing algorithm requires a one-way interaction with the control facility, although the ground link can support information transfer in the reverse direction if desired. The interaction takes place by means of an IPC-generated message referred to as "controller alert," which describes the state of a conflict between two aircraft. For a controller alert to be generated, at least one aircraft involved must be IFR; however, either or both aircraft may be ATCRBS-equipped (Mode C), rather than DABS-equipped. When a conflict involves more than two aircraft, a separate conflict alert will be generated for each pair (but always containing consistent data for a given aircraft). A controller alert is initially transmitted as a 2-minute warning and is retransmitted with updated information as needed for the duration of the conflict.

For VFR-IFR conflicts, the first (2-min) alert serves as an advisory to the controller. He has the option of vectoring the IFR aircraft to resolve the conflict. If the conflict persists, IPC will issue a maneuver command to the VFR aircraft when the warning time has decreased to 75 seconds, and a new conflict alert will be sent to inform the controller. For IFR-IFR conflicts, alert messages are transmitted in a similar manner, but commands are not issued on the uplink except as a backup to the controller when the conflict persists and time becomes critical. The IPC will always compute maneuver commands as needed for both aircraft and include them both in controller alert messages even though the command cannot be delivered to a non-DABS-equipped aircraft and is normally not delivered to an IFR aircraft even if DABS-equipped. In these cases, the computed maneuvers may be useful as advisories and when there is a situation in which the controller is requested to relay the maneuver command by voice link. This is the case in which a command is to be issued to an IFR aircraft, but that aircraft is not DABS-equipped or its uplink is failing.

The controller alert message format includes the following data for each of the two aircraft [Ref. 7]: aircraft identifier (DABS or ATCRBS ID), control status (IFR/VFR), equipment type (DABS/ATCRBS), aircraft location in XYZ coordinates, aircraft velocity (also XYZ), currently computed horizontal and vertical maneuver commands, a flag to indicate whether or not the pilot has acknowledged the commands, and a flag that requests the controller to relay the message by voice.

The principal actions of the ATC facility in handling a controller alert message include routing of the message to the proper controller station, and display of the message contents, perhaps on the output device used for pilot messages.

The operational implications of IPC are complex and will be studied in an ATC environment as part of DABS/IPC testing at NAFEC. Regarding DABS-ATC interactions, some questions that should be explored are: (1) what is the best handling of IPC uplink messages that are pilot advisories (PWI) rather than commands? (2) how does the controller make use of alert information as well as data provided by a conflict detection function within the ATC automation if both are available? and (3) should the system transmit information from the controller to IPC, such as his own commands to IFR aircraft?

4.1.2 IPC Recording System Messages

For administrative and legal reasons, it is necessary to make a complete recording of IPC-generated transactions. The preferred location for such a recording system would be at the IPC processor itself where most, if not all, of the desired information is generated. However, IPC is intended to operate at unmanned DABS sites, and a wholly automatic tape recording system is not considered feasible. Therefore, it is planned that the recording system be located at ATC facilities. In a multisite IPC configuration, this implies that certain ATC facilities would house the recording system for more than one IPC site.

Two types of messages are transmitted from DABS for recording system purposes. They contain information that overlaps to a considerable extent with that of controller alert messages; nevertheless, they do contain some additional data that is needed. It may also be desirable to record additional material such as pilot acknowledgment messages (particularly if the PBUT channel from which these arise is exclusively linked to the pilot's IPC display), and possibly controller alert messages. Details of the two message types follow.

A. Duplicate IPC Uplink Message. A "duplicate IPC uplink message" is generated by the IPC processor whenever a positive or negative maneuver command is generated for transmission.* Note that commands that are not actually transmitted (such as those for non-DABS-equipped aircraft) are not included, even though they are included in controller alerts. The format of a duplicate IPC uplink message, except for a distinctive type code, is precisely that of the IPC-generated tactical uplink message that it duplicates. The action of the DABS sensor, upon receiving this message, is simply to route it appropriately to the ATC facility. Upon its receipt at the ATC facility, it is routed to the IPC recording system. No other use of this message is anticipated.

B. Duplicate IPC Message Delivery Notice. A "duplicate IPC message delivery notice" provides for the recording of the technical acknowledgment (or delivery failure) of an IPC uplink message. This type of message is generated within the DABS sensor which attempts uplink delivery, rather than within the IPC function itself. The distinction becomes significant in a multisensor configuration. In this configuration, an IPC processor may transmit a command via some sensor other than the one with which it is collocated. (This option will be exercised when the collocated sensor is experiencing link failure.) The resulting duplicate message delivery notice will originate with this second sensor rather than the collocated sensor. Information is provided in the message to establish the routing history.

The message format is that of an ordinary message delivery notice (including referenced message number) but with the addition of a "referenced sender ID" field. This field contains the sensor ID code of the originating IPC. It will therefore match the implicit sensor code of the duplicate IPC uplink message. This match, together with a match between the explicit "message number" and the "referenced message number," permits the association to be reconstructed.

The DABS sensor generates the duplicate delivery notice and routes it to the cognizant ATC facility at the same time that it generates an ordinary delivery notice and routes it to the originating IPC. Upon receipt at the ATC facility, the main task is to route it to the IPC recording system. It may be desirable to make it available also to the controller as an adjunct to the controller alert information. The reason for this is that the controller alert, as presently defined, does not contain technical acknowledgments, although it does include pilot responses.

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*It is unclear at present whether or not PWI messages will be included as well.

4.2 Performance/Status Interactions

4.2.1 DABS Sensor Status Reporting

Continuous knowledge of the status of DABS sensors is important to an ATC facility for two reasons. First, it is necessary to observe the reliable functioning of the sensors as part of an ongoing monitoring of overall ATC performance. Second, since DABS sensors operate in general as remote unmanned stations, it is important to observe malfunctions that should result in nonscheduled maintenance or repair activity. The following four types of messages are concerned with monitoring the conditions of a sensor and related activities.

A. Test Message. A "test message" and the resulting response comprise a transaction that can be initiated by either a sensor or an ATC facility. The message formats are the same in each case. The test message format simply contains 48 data bits that are not specified at this time. These may consist of an arbitrary code, either fixed or variable. The precise use of a test transaction is also not presently determined, but it will be desirable at least during sensor startup and as part of a sensor/ATC facility interface checkout mode. It may also be useful as a diagnostic tool when certain types of errors or failures are reported. Whether or not it will be more generally useful during normal operations is unclear. A test transaction will serve to verify proper operation of the ground link and some of the sensor software (minimally, message routing and a test response routine).

B. Test Response Message. The "test response" message is issued by the receiving station in response to a test message. It also consists of an unspecified 48-bit data field, which may contain the same bit pattern as that of the test message. No basis for more elaborate processing to produce a different output code has been determined.

C. Status Message. The "status message" is the most important type in this category. Its format is not defined at present (and it therefore does not appear in Appendix B). However, its information contents are specified in Reference 8, Section 3.4.10. Each DABS sensor issues a message of this type once per antenna scan period to each ATC facility to which it is linked. Determination of status is the task of the performance monitoring function [Ref. 8] within each sensor. Performance monitoring regularly performs many tests on the operation of other functions within the sensor, both hardware and software. Among the hardware parameters checked are transmitter and receiver power calibration, monopulse outputs, real-time clock status, and azimuth register status. Software checks include the overflow status of various queues and buffers, the number of tracks in each of various states, and the number of uplink messages delivered and expired.

In addition, inputs are included from Calibration and Performance Monitoring Equipments (CPMEs). These are transponder-like devices at known ground locations, and their replies provide a check on software and hardware relating to uplink modulation and transmission, downlink reply processing, and data link and surveillance processing, including position measurement calibration. All of these inputs enter into a determination of the sensor status category (normal operation, marginal operation, or failure). Status category is issued by the network management function to adjacent DABS sensors. A failure status causes these adjacent sensors to modify their coverage assignments in a predetermined manner so as to acquire the target load of the failed sensor.

The types of information included in a status message are: sensor loading statistics (the numbers of DABS and ATCRBS tracks), the status category of the sensor and its associated IPC function, and the specific condition that has resulted in any declaration of marginal or failed status. As long as normal operation obtains, therefore, the message is brief, and the ATC facility is not burdened with masses of detailed performance data. When there is a non-normal status, the particular problem area is indicated. Status messages, as received at an ATC facility, should be routed not to a controller but to a suitable output device convenient to the person responsible for overseeing facility operation. He will be able to monitor sensor difficulties as they develop and take appropriate actions.

The nature of such actions remains to be explored. If a network of DABS sensors is in operation with heavy multiple-coverage capability, it may be that no action is necessary (other than initiating DABS sensor maintenance or repair as needed). If there is only one sensor in the area, the operations manager may advise controllers of the problem and instruct them, for example, to use voice instead of the DABS air link when the problem affects message delivery.

D. Track Alert Message. The "track alert message," in contrast with the status message, is intended to inform ATC regarding a highly specific, low probability error condition. This condition is the presence, in the sensor surveillance file, of two distinct tracks carrying the same DABS address. Since DABS transponders are designed to encode a unique hard-wired address, this duplicate address situation can only arise if (1) either a transponder or the sensor makes a systematic error that converts the true address into a different address in a consistent manner, and (2) another aircraft happens to be in track at the same time and its DABS address matches the erroneous one.

The track alert message format contains the DABS address in question and the position (range and azimuth) of each of the two tracks. Upon receipt of the message, it should be routed to the surveillance processing software where the information may be readily used to make the desired associations. In order to avoid confusion, the track files of the aircraft involved could be flagged, and further data on each of them processed with a special report-to-track correlation algorithm. This algorithm could simply handle the aircraft reports as lacking unique codes and correlate on position only. Further updating of the two tracks could be based only on track alert messages, as long as the duplicate address condition persists.

Within the DABS sensor that detects a duplicate address condition, a further action is to delete the address from the interrogation roll call so that surveillance on both aircraft is maintained by use of the all-call mode only. As a result, the DABS uplink is no longer available for the aircraft as long as the problem persists. This implies that the track alert message information should be suitably displayed to the controller so that he will not attempt uplink messages. The dropping of discrete interrogations to the aircraft in question will also cause a "loss of DABS contact" condition in the transponders. This event should result in a voice inquiry by one or both pilots to the controller who may then be able to resolve the ambiguity.

It should be noted that a similar error condition may arise in which two aircraft simultaneously report the same DABS address to two different DABS sensors, which in turn report to the same ATC facility. If there is non-overlapping coverage of the particular two aircraft, then each sensor is aware of only one aircraft, and the DABS system cannot alert the ATC facility to the situation. This suggests that it may be considered desirable to have the capability to detect a duplicate DABS address situation built into the facility software in the multisensor case.

4.2.2 ATC Facility Status Reporting and Control

Finally, there is a miscellaneous group of interactions initiated by the ATC facility to report its own status and to provide the DABS sensor with certain control information. It should be noted that no interactions are defined that provide for direct operational control of the sensor, i.e., there are no messages that affect such situations as DABS transmission modes, setting of lockout states or coverage boundaries, software mode selection, etc. This reflects the design philosophy that DABS sensors should function autonomously except for nonroutine maintenance, once they have completed checkout and are in operational mode. If any desirable operational control features are identified as a result of DABS engineering model testing at NAFEC, they may, of course, be added. The following paragraphs discuss each of the five message types presently defined:

A. The test message has been treated in Section 4.2.1, Item A.

B. The test response message has also been discussed in Section 4.2.1, Item B.

C. Altimeter Correction Message. The "altimeter correction" message is the only means by which a DABS sensor learns the correct current values of altimeter pressure corrections. These values are to be applied to the encoded altimeter readings received on the downlink from all DABS-equipped aircraft and uplinked as the "altitude echo" to provide the pilot with a verification of the direct readout of his onboard altimeter. This automatic uplinking of corrected altitude will serve initially to inform the pilot of the correction to be manually set in, although the present method involving the controller and the voice link will continue to be available as a backup. It is clear that properly updated correction values are important to DABS operation.

Altimeter correction is a function of geographic area, and some sensors may need to know more than one value if their coverage extends beyond one such geographic region. The data values are supplied by ATC facilities in a fully predetermined manner. Some terminal ATC facilities may not be involved in transmitting this data at all, while some enroute facilities may support several sensors. For each ATC facility/DABS sensor pair, there is a fixed set of correction regions. The correction message contains the number of corrections followed by the data values, encoded as signed BCD characters giving altitude in hundreds of feet. Upon its receipt, the message is routed to the appropriate software routine that stores the data, interpreting it according to prearranged map regions. Note that the format requires a complete set of corrections even though not all of them may be updated.

In order to generate this type of message, the ATC facility needs to implement a means of handling the data in software after receiving it from its original source. Data input could be accomplished manually following receipt of the information via off-line communications, or it could be a direct automatic function. Each new input would have to be associated in software with one or more particular message data slots (e. g., correction data from region A updates the third data field for sensor B, the first for sensor C, etc.). The messages may be issued whenever one new correction value is entered or else periodically according to a fixed schedule.

D. NAS Failure/Recovery Message. The "NAS failure/recovery" message is intended to signal operation status to DABS and to IPC. The format, as presently defined, includes a single data field that takes on any of three values: failure, recovery from failure, and recovery from failure with loss of data base. These states are not really defined at this time, nor is the process by which the facility's state is to be determined. It may be that a function resembling a DABS sensor's performance monitoring should be implemented to generate a status determination automatically. If this were done, the message could be modified to include a more specific indication of the area of failure.

DABS handling of a received message of this type is also not defined. Presumably, receipt of a "failure" notice would cause changes in the dissemination of surveillance and downlink message data, and "recovery" would re-establish normal dissemination. "Recovery with loss of data base" might trigger the sending of some additional information from the sensor surveillance file to facilitate rebuilding of the normal data base. A "failure" indication may also result in use of a back-up version of the IPC algorithm. The inclusion of this message type has been intended to provide for possible back-up support modes and to promote thinking about operational requirements for such support.

E. All Radar Data Request Message. The "all radar data request" message supports a special function within ATC facility software concerning registration of aircraft position data from different sensor sites. In order to perform such registration or calibration on radar data, it is desirable to receive search messages for all targets rather than only those that do not correlate with beacon tracks. (See Section 2. 1. 7 for a summary of DABS rules for normal surveillance data dissemination.) The message and the associated use of the resulting data might be generated by a simple manual input or automatically by software.

The message format contains a single two-valued parameter that indicates the start or stop of the all radar data mode. Upon its receipt at a DABS sensor, the message is routed to the dissemination function within surveillance processing. A "start" value causes the sensor to pass on (to the requesting facility only) all search messages. This data stream is transmitted in addition to all the normal surveillance outputs. The existence of this mode is of course optional for any particular ATC facility, and it has no effect on DABS functions other than data dissemination.

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[4] G. V. Colby, P. H. Robeck, and J. D. Welch, "Provisional Data Link Interface Standard for the DABS Transponder," Project Report ATC-34, Lincoln Laboratory, M. I. T., FAA-RD-74-64 (25 April 1974).

[5] "ATC Message Display," Federal Aviation Administration Engineering Requirement, FAA-ER-240-36a (18 November 1974).

[6] E. J. Kelly, "DABS Channel Management," Project Report ATC-43, Lincoln Laboratory, M. I. T., FAA-RD-74-197 (8 January 1975).

[7] "Multisite Intermittent Positive Control Algorithms for the Discrete Address Beacon System," MTR-6742, The MITRE Corporation, FAA-EM-74-4 (September 1974).

[8] "Discrete Address Beacon System (DABS) Sensor," Federal Aviation Administration Engineering Requirement, FAA-ER-240-26 (1 November 1974).

APPENDIX A

SURVEILLANCE REPORT FORMATS FROM DABS TO ATC

The tables on the following pages, Tables A-1 and A-2, summarize the formats of surveillance reports described in detail in reference 1.

TABLE A-1

SURVEILLANCE MESSAGE FORMATS (BEACON)

Bit	DABS	ATCRBS
1	Test	Test
2	1	1
3	1	1
4	1	0
5	P/S	Mode 3/A
6	Mode C	Mode C
7	S	SPI (Ident)
8	Radar Reinf.	Radar Reinf.
9	Code 7700	Code 7700
10	Code 7600	Code 7600
11	FAA	FAA
12	Radar Substitution	Radar Substitution
13	PARITY	PARITY
14	MSB = 128	MSB = 128
15		
16		
17		
18		
19		
20	Range	Range
21	(nmi)	(nmi)
22		
23	(cont.)	(cont.)
24		
25		
26	PARITY	PARITY

S = Spare hit.

TABLE A-1

SURVEILLANCE MESSAGE FORMATS (BEACON)
(continued)

Bit	DABS	ATCRBS
27 28 29	Range (nmi) (cont.) LSB=0. 0078	Range (nmi) (cont.) LSB=0. 0078
30 31 32 33 34 35 36 37 38 39	MSB = 180 Azimuth (deg) PARITY	MSB = 180 Azimuth (deg) PARITY
40 41 42 43	LSB=0. 044	LSB=0. 044
44 45 46 47	Alert FR S Data Relay	Confidence Code in Transition False Target Data Relay
48 49 50 51 52	MSB = 1 Time in Storage (sec) LSB = 1/8 PARITY	MSB = 1 Time in Storage (sec) LSB = 1/8 PARITY

TABLE A-1

SURVEILLANCE MESSAGE FORMATS (BEACON)
(continued)

Bit	DABS	ATCRBS	For Radar Substitution (Bit 12 = 1)
53		A_4	
54		A_2	
55		A_1	
56	DABS Address	Mode 3/A Code B_4	
57		B_2	
58		B_1	
59		C_4	
60		C_2	
61		C_1	
62		D_4	
63		D_2	
64		D_1	
65	PARITY	PARITY	
66			Possible spares (ATCRBS only)
67			Possible spares (ATCRBS only)
68		ATCRBS Surveillance File Number	
69			
70			
71			
72			
73			
74			
75			
76			
77			
78	PARITY	PARITY	
79	Sign: 0=Pos, 1=Neg	Sign: 0=Pos, 1=Neg	MSB = 16
80	MSB=102400	MSB=102400 ft.	Run Length (ACP)
81			LSB = 4
82	Mode C Altitude (feet)	Mode C Altitude (feet)	S
83			S
84			S
85			S
86			S
87			S
88			S
89			S
90	LSB = 100	LSB = 100	S
91	PARITY	PARITY	PARITY

TABLE A-2

SURVEILLANCE MESSAGE FORMATS (PCD)

Bit	Search	Strobe	Map	Status	Search RTQC TGT
1	TEST	TEST	TEST	TEST	1
2	0	0	0	0	0
3	0	0	0	0	0
4	1	1	0	0	1
5	1	1	0	1	0
6	0	0	0	1	0
7	1	0	0	0	1
8	1	0	Map Variation	0	0
9	0	Strobe Variation		0	0
10	0			0	0
11	FAA	FAA	FAA	FAA	FAA
12	AF	AF	AF	AF	AF
13	PARITY	PARITY	PARITY	PARITY	PARITY
14	MSB=128	MSB=128	MSB=128	Radar Alarm	0 MSB=128
15				Beacon Alarm	0
16				CD Alarm	0
17	Range	Range	Range Start	0	0 (Range)
18	(nmi)	(nmi)	(nmi)	0	0 (nmi)
19				AIMS Alarm	0
20				Standby Radar Alarm	0
21				Standby Beacon Alarm	1
22				Standby CD Available	0
23				0	0
24	LSB=0.125	LSB=0.125	LSB=0.125	HPG Reg. Line Alarm	0 LSB=0.125
25	0	0	0	0	0
26	PARITY	PARITY	PARITY	PARITY	PARITY

TABLE A-2

SURVEILLANCE MESSAGE FORMATS (PCD)
(continued)

Bit	Search	Strobe	Map	Status	Search RTQC TGT
27	MSB=2048	MSB=2048	MSB=2048	HPG Req. Parity Alarm	MSB=2048
28				0	
29				DSG Alarm	
30	Azimuth	Azimuth	Azimuth	0	Azimuth
31	(ACP)	(ACP)	(ACP)	0	(ACP)
32				0	
33				0	
34				Sens. Det. On	
35				R. L. Discr. On	
36				Normal Sector 3	
37				Normal Sector 2	
38	LSB = 1	LSB = 1	LSB = 1	Normal Sector 1	LSB = 1
39	PARITY	PARITY	PARITY	PARITY	PARITY
40	AIMS Present	MSB=256		Outer Contour	MSB=256
41	MSB AIMS Code			Inner Contour	
42	LSB AIMS Code	Run Length		Fixed Map On	Run Length
43	MSB=16	(ACP)	Range Stop	High Speed Timing Alarm	(ACP)
44	Run Length (ACP)		(nmi)	1/2 Scan Inhibit Alarm	
45	LSB = 4			Buffer Overload Alarm	
46	MSB = 4	LSB = 4		0	LSB = 4
47		MSB = 2		0	MSB = 2
48	Time in Storage			0	
49	(sec)	Time in Storage		Sensitive Sector 3	Time in Storage
50		(sec)	LSB=0.125	Sensitive Sector 2	(sec)
51	LSB=1/8	LSB=1/8	0	Sensitive Sector 1	LSB=1/8
52	PARITY	PARITY	PARITY	PARITY	PARITY

APPENDIX B

LINK DATA FIELD FORMATS

The tables on the following pages, Tables B-1 and B-2, summarize the link data field formats of messages that pass between DABS and NAS for air-ground communications and other purposes. These formats are described in detail in Reference 1 (as modified by Change 1, 13 November 1974).

TABLE B-1

LINK DATA FIELD FORMATS FOR NAS-TO-DABS MESSAGES

18-4-16268-2

Tactical Uplink

0 0 1 0 0 0 0 1	DABS Address	MSG. No.	EXP	P	SC	MA (repeated)
1–8	9–32	33–36	37–39	40	41–42	43–98

ELM Uplink

0 0 1 0 0 0 1 0	DABS Address	MSG. No.	EXP	Length	ELM Text (Max 1280)
1–8	9–32	33–36	37–39	40–43	44

Request for Downlink Data

0 0 1 0 0 0 1 1	DABS Address	MSG. No.	EXP	P	MSRC
1–8	9–32	33–36	37–39	40	41–44

ATCRBS ID Request

0 0 1 0 0 1 0 0	DABS Address	MSG. No.
1–8	9–32	33–36

Message Cancellation Request

0 0 1 0 0 1 0 1	DABS Address	MSG. No.	Ref. MSG. No.	Ref. Type Code
1–8	9–32	33–36	37–40	41–48

Test Message

0 1 1 0 0 0 0 1	Test Data
1–8	9–56

Test Response Message

0 1 1 0 0 0 1 0	Test Response Data
1–8	9–56

Altimeter Correction Message

1 0 0 1 1 0 1 1	N	Alt. Cor. (repeated)
1–8	9–12	13–20

NAS Failure/Recovery Message

1 0 0 1 1 0 0 1	State
1–8	9–10

All Radar Data Request

1 0 0 1 1 0 1 0	SS
1–8	9–10

Data Link Capability Request

0 0 0 0 0 0 1 0	DABS Address
1	9–32

TABLE B-2

LINK DATA FIELD FORMATS FOR DABS-TO-NAS MESSAGES

18-4-16269-5

Message Rejection Notice

0 0 1 1 0 0 0 1	DABS Address	Ref. Msg. No.	Qual.
1 8	9 32	33 36	38

Message Delivery Notice

0 0 1 1 0 0 1 0	DABS Address	Ref. Msg. No.	DI
1 8	9 32	33 36	37

Tactical Downlink

0 1 0 0 0 0 0 1	DABS Address	MB
1 8	9 32	33 88

ELM Downlink

0 1 0 0 0 0 1 0	DABS Address	Length	ELM TEXT (Max. 1280)
1 8	9 32	33 36	37

Pilot Acknowledgment

0 1 0 0 0 0 1 1	DABS Address	PBUT
1 8	9 32	33 34

Data Link Capability

0 1 0 0 0 1 0 0	DABS Address	Capability
1 8	9 32	33 38

ATCRBS ID Code

0 1 0 0 0 1 0 1	DABS Address	ATCRBS ID
1 8	9 32	33 44

Controller Alert Notice

1 0 0 0 0 0 1 1	Defined in FAA-EM-74-4
1 8	9

Test Message

0 1 1 0 0 0 0 1	Test Data
1 8	9 56

Test Response Message

0 1 1 0 0 0 1 0	Test Response Data
1 8	9 56

Track Alert Message

1 0 0 1 1 1 0 0	DABS Address	Range (1st)	Azimuth (1st)	Range (2nd)	Azimuth (2nd)
1 8	9 32	33 47	48 60	61 75	76 88

Duplicate IPC Uplink Message

1 1 0 0 0 0 0 1	DABS Address	MSG. No.	EXP	P	SC	MA (repeated)
1 8	9 32	33 36	37 39	40	41 42	43 98

Duplicate IPC Message Delivery Notice

1 1 0 0 0 0 1 0	DABS Address	Ref. Msg. No.	DI	Ref. Sender ID
1 8	9 32	33 36	37	38 41