NASA Contractor Report 4074

Development of an Air Ground Data Exchange Concept: Flight Deck Perspective

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ABSTRACT

The planned modernization of the U. S. National Airspace System (NAS) includes the development and use of digital data link as a means to exchange information between aircraft and ground-based facilities. This report presents an operationally-oriented concept on how data link could be used for applications related directly to air traffic control. The specific goal of this research effort is to establish the role that data link could play in the air-ground communications. Due regard is given to the unique characteristics of data link and voice communications, current principles of air traffic control, operational procedures, human factors/man-machine interfaces, and the integration of data link with other air and ground systems. The resulting concept is illustrated in the form of a "paper-and-pencil" simulation in which data link and voice communications during the course of a hypothetical flight are described.

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1. INTRODUCTION

In order to meet the projected increase in demand for airspace and airport resources, and to increase the safety and efficiency of the air traffic control (ATC) system, the U.S. government has embarked on a large-scale upgrade of the National Airspace System (NAS). New communications, navigation, and surveillance technologies are being developed and, when coupled with increasing levels of automation afforded by powerful airborne and ground-based computers, offer significant potential for meeting future demands. The development and use of a data link (d/l) to support a wide variety of information exchanges between aircraft and ground-based facilities is considered an important element of the planned NAS improvements. When compared with the voice radiotelephone (r/t) which currently supports most of the air-ground information exchanges in the ATC system, d/l is superior in terms of the speed, accuracy, and volume of data which can be transferred. Thus, more advanced air traffic concepts which require a more capable communications link are made possible.

However, while there are technical advantages in the use of d/l for air-ground information exchanges, there are certain desirable features of r/t that should be preserved in the evolving communications system. Though standard phraseology is normally used to reduce errors in communications, there is wide latitude in the way information is expressed with r/t such that a common understanding between the pilot and controller can be quickly reached in unusual situations. In addition, because the pilot (or controller) is always involved in the generation or receipt of an r/t message, the human is constantly aware, or "in the loop," of information exchanges. Desirable characteristics such as these should be factored into the development of tomorrow's ATC communications system.

In this paper the use of d/l in an airborne operational context is examined, with the intent of describing the role it could play as part of a future communications system. The major emphasis is on the operational factors that must be addressed for successful implementation of d/l, rather than the technical issues. The use of d/l in the ATC system will likely cause fundamental changes in the ways pilots and controllers perform their tasks because there is more to the advantageous use of d/l than simply rehosting r/t messages on a digital medium. Therefore, under the assumption that the technical challenges to fielding a digital link can be addressed, this paper describes a potential way it could be used operationally to the advantage of airspace users and the ATC system.

1.1 Background

Although the use of d/l for ATC-related information exchange represents a new application for this technology, various forms of d/l have been used in other ways for a number of years in civil and military aviation. A very basic form of d/l exists in the current Air Traffic Control Radar Beacon System (ATCRBS) which was designed primarily to enhance surveillance capabilities in the NAS. By squawking an ATC-assigned transponder code, an aircraft can be uniquely identified and tracked by the ATC surveillance system (this is ATCRBS Mode A). In addition, provisions in the signal format enable the aircraft to also transmit its digitally-coded pressure altitude (called ATCRBS Mode C). So, in a sense, ATCRBS represents a d/l between the aircraft and ATC facilities even though it is not expressly used as an information exchange medium between the pilot and controller.

Another example of a d/l primarily intended for air-ground data exchange in the U.S. is in the Arinc Communications Addressing and Reporting System (ACARS) (Reference 1). This is a privately maintained VHF d/l used by airlines and other subscribers for company-related air-ground communications. Each participating aircraft is assigned a unique digital address. Through an on-board control unit, the crew may engage in data communications with their flight dispatch office or other facility via a series of ground-based transceivers and an associated ground-based data transmission network. The major applications of ACARS include the automated filing of Out, Off, On and In reports by aircraft, transmission of engine and performance parameters for maintenance monitoring purposes, and transmission to aircraft of operational data such as weight and balance information and weather observations. The widespread use of ACARS to facilitate the exchange of routine operational data between aircraft and company facilities is indicative of the potential d/l has as part of a future communications system.

In recent years the Federal Aviation Administration (FAA) and the aviation industry have been developing a more functional d/l as part of the improved ATCRBS surveillance system. This system, known as Mode S, is basically an extension to the current ATCRBS Mode A and C in which each aircraft transponder is assigned a unique address code which remains assigned to that aircraft (i.e., it does not change from flight to flight as in the current Mode A scheme). This allows the ground-based surveillance system to selectively interrogate transponders in its coverage area, thereby reducing some of the surveillance problems associated with the current ATCRBS. It also allows a d/l communications path to be formed between the ground and selected aircraft when digital messages are incorporated into the interrogation-response signal format. At present, the Radio Technical Commission for Aeronautics (RTCA) has adopted Minimum Operational Performance Standards (MOPS) for the surveillance portion of Mode S airborne equipment (Reference 2), and is now developing MOPS for the d/l portion. In addition, the FAA has issued a Notice of Proposed Rulemaking (NPRM) which establishes a timetable for the transition to the d/l-capable ATCRBS Mode S system (Reference 3).

Many organizations have participated in development and tests of Mode S over approximately the past ten years. In work sponsored by the FAA, MITRE supported the procurement of Mode S ground sensors and the development of national and international standards for Mode S airborne equipment. Since the FAA has determined that weather information will be an initial application of the Mode S d/l, MITRE has also drafted requirements to coordinate the development of components to provide these early weather products (Reference 4). Weather products were picked for the initial application of Mode S d/l, in part, because the weather data base would be in place before the first Mode S installation and also because the operational factors associated with requesting and receiving this type of information on d/l are comparatively simple. MITRE has also prepared for the FAA a list of potential d/l services to extend beyond those provided in the initial applications (Reference 5). However, the objective of this work was only to list potentially feasible services that might be performed through d/l as part of the NAS modernization effort. Although a "sequence of actions" was speculated for each example of potential services, it was not intended to be interpreted as an exhaustive treatment of the operational issues associated with a particular service.

The FAA has recently commissioned development of a draft d/l service development plan (Reference 6), which is largely based on the list of candidate d/l services listed in Reference 5, for agency review and comment. This draft document describes the programmatic approach the FAA may take to implement Mode S d/l in the evolving NAS. It includes the coordination that will be necessary between various branches of the FAA, and expected user and industry participation. Time schedules showing the interdependencies of program efforts are included. The plan does not identify an operational concept for the use of d/l, but rather treats services individually from the definition stage through implementation.

The potential for satellite-based d/l for civil aviation use is also under active investigation. Simulations and actual flight tests have been performed using a commercial satellite for the space segment of a satellite d/l with aircraft (Reference 7). These tests have demonstrated that such a system can provide reliable data communications, especially in areas where r/t coverage is poor or non-existent. Satellite d/l is also receiving the attention of the International Civil Aviation Organization (ICAO) as a potentially important part of the future air traffic system (Reference 8).

In addition to the potential and actual applications of d/l in a civil aviation environment, there are scores of additional examples of d/l in military applications which further prove its viability as a future communications tool in the ATC system. The U.S. Navy, for example, has used d/ls since the early 1960's to support tactical command control and communication functions in airborne and marine operations (Reference 9).

This brief synopsis of applications and research and development activities is indicative of the technical potential d/l has for reaching NAS Plan objectives. D/l technologies have matured in non-aviation applications and in some regards have become a routine means of communicating data. In aviation-related applications the technical challenges of establishing and using a d/l are well within reach.

However, in spite of the technical progress made with d/l, there remain several operational issues which must be considered in its development as a device for ATC communications. These issues include the operational procedures and protocols that humans (pilots and controllers) will use to effectively communicate with one another, the integration of d/l with accepted principles of air traffic control and with other air and ground systems, and the design of appropriate man-machine interfaces. For these major issues to be resolved they must be considered first at the "systems" level where the role d/l will play in the ATC environment is clearly defined: they cannot be adequately treated if the analysis is performed on d/l as an isolated element and without regard for d/l's total role in the ATC system.

The amount of work done on these operational aspects of d/l has not kept pace with technical advances. One study that did have an operational emphasis was sponsored by the NASA-Langley Research Center in which a d/l was simulated to provide pilot-subjects with ATC instructions (Reference 10). It demonstrated that d/l is feasible for this purpose, and concluded that a voice back-up communications capability was considered desirable. However, because this effort was aimed at demonstrating the feasibility of using d/l particularly as a means to reduce cockpit workload, it did not address potential problems such as those associated with "mixed-mode" communications (i.e., instances where both d/l and r/t are used for air-ground communications), nor did it consider the operational issues facing the air traffic controller.

Other simulations and flight tests have been conducted on prototype d/l terminals and communications procedures, and results of these efforts were useful in revealing areas which would need attention in further developing d/l as an ATC communications tool. The Federal Republic of Germany, for example, recently conducted an investigation of airborne interfaces for d/l (Reference 11), and determined that the introduction of a d/l terminal in the cockpit for ATC messages did not disrupt pilots from their operating tasks, and the results reinforced the idea that the ATC system and its users can benefit from the capabilities of d/l communications.

More studies have been performed on cockpit input/output and display devices, especially as computer-stored data and menu driven display processes are becoming increasingly popular in newer aircraft. As an example, Reference 12 describes the results of simulator evaluations of various types of airborne displays of ATC information that could be received through d/l. Like other studies it concluded that d/l suitably reduced workload in the cockpit and was generally accepted by the broad spectrum of pilot-subjects who were involved. However, the emphasis was on the feasibility of using displayed information, rather than evaluating the potential for blunders or improvements with the incorporation of d/l. Studies by the major airframe manufacturers on advanced cockpit design provide additional examples of the work that has been performed in the area of airborne displays and input/output devices (References 13, 14, and 15). No emphasis has been put, however, on how d/l is to be used for ATC purposes in the operational environment.

Although d/l has long been proposed as a concept for future systems, little work has been performed to date on the integration of d/l with other elements of airborne (or ground) automation and the extent to which humans need to be in the loop of automatic data exchanges. In support of earlier work on advanced automation of the ATC system, MITRE prepared papers describing how data link could fit into the evolving ATC system (References 16 and 17). These presented high level concepts that were intended to stimulate thought on how data link may be used to realize certain benefits in the ATC system; they did not address operational considerations that could be anticipated in day-to-day operations.

While these research efforts have been useful in gaining an initial understanding of the issues facing d/l implementation, there is still a need to take an assessment of the air-ground communications needs of the ATC system, the capabilities of both r/t and d/l technologies, and organize them in a comprehensive description of a future ATC communications system. It seems clear that such an operational concept for the use of d/l is necessary to further develop applications and to provide direction for future research and simulations. This operational concept should be the result of a taking an overall systems approach, including aspects of the information exchange process such as controller and pilot roles, man-machine interfaces, expectations and habits, and procedural understandings. D/l can be expected to change the manner in which pilots and controllers reach operating agreements, so the procedural issues in using d/l are at least as important as the technical ones.

1.2 Objectives, Scope, and Assumptions

The primary objective of this research effort was to examine ATC applications of d/l and r/t communications and develop a systems concept which addresses those operational aspects mentioned above. Given the limited scope and objectives of previous research efforts in this area, it was considered desirable to provide a comprehensive system description in which the role of d/l in ATC communications is clearly defined. Using this initial system description, which may be refined and improved based on review and input by various experts, research programs may be better focused.

To make the effort manageable in light of various issues it must address, the scope of the work is limited to pilot and controller operational considerations in the communications process. In the context of the Open Systems Interconnect (OSI) model (Reference 18), which partitions the various functions which must be performed for multiple users to be "linked" together to conduct data communications, this effort concentrates mainly on the "applications" layer. This is the highest level of the OSI model and describes how the data are being used, or created, by participants on the network.

It is assumed that the lower layers of the OSI reference model, that is, those associated with the mechanics of the data exchange itself, have been addressed separately. This is a reasonable assumption because it is more desirable to have the applications govern the design of the mechanics of the link, rather than have the mechanical limitations of a link constrain the development of useful applications. In addition, in view of the many different d/l technologies already in use, it can be safely assumed that it is technically feasible to develop appropriate link mechanics for any intended application, once the application is identified.

With the operational emphasis of this research, it is also not necessary to assume that the d/l takes the form of a specific system which is in use or under development. The simple application of d/l to support ATC communications has such profound operational considerations that the type of d/l being used is of secondary importance at this point. Therefore, no assumption is made that the d/l in use is Mode S, or satellite-based, or VHF (similar to ACARS), etc. It is quite possible, in fact, that more than one d/l will be in place to support air-ground data communications and that some aircraft may be equipped with more than one link.

The assumed operational environment in which this developmental effort takes place is primarily today's ATC system with reasonable extensions made for possible future ATC capabilities. While d/l is considered an essential element of advanced ATC concepts such as time-based separation, metering, and spacing, it should first be demonstrated that d/l can support some of the simpler procedures of today's environment (such as speed, altitude, and heading commands). When this can be demonstrated, it is not an unreasonable jump to the consideration of advanced ATC concepts, as many of them still involve the simpler speed, altitude, and heading instructions. Therefore, primary consideration is given to the use of d/l to support the kinds of ATC procedures which are prevalent in the NAS today.

Finally, because the goal is to provide a systems level description of a communications system of which d/l is a central part, emphasis is placed on the information exchange process rather than on the hardware. While man-machine interface issues are very important to d/l applications and are considered in this report, it is assumed that more detailed issues such as symbology, Input/Output (I/O) options, and other interface issues will be addressed in subsequent research efforts.

1.3 Approach

The approach taken in this project was comprised of three parts: 1) analyzing current ATC procedures and communications as performed by r/t, 2) establishing system design goals which recognize the operational characteristics of both d/l and r/t communications, and 3) developing, evaluating, and refining the system concept. FAA handbooks and manuals and other available literature were reviewed to provide a comprehensive list of ATC-related r/t messages. Representative messages were placed in an "operational" context through the development of a scenario in which the r/t message exchanges of a hypothetical flight were tabulated. The scenario served as a tool for illustration and analysis of the voice communications process. From the scenario, the desirable and non-desirable characteristics of r/t communications were identified and became, in part, the basis for establishing the system design goals of the d/l and r/t communication concept. The concept was then developed from "scratch" and reviewed and refined by exercising it on a data link version of the same scenario.

1.4 Organization of Report

The methods used to characterize r/t communications in today's ATC environment are described in Section 2. Section 3 describes the system design goals which resulted from this analysis of r/t communications and the resulting system concept. Section 4 summarizes the major findings of this report, and also recommends areas for future research. Appendices A and B, respectively, present the r/t and d/l versions of the same flight scenario. A set of standard ATC r/t messages is provided in Appendix C.

2. ANALYSIS OF CURRENT ATC RADIOTELEPHONE COMMUNICATIONS

An initial step in developing the concept for an information exchange system was the analysis of r/t communications as they are now conducted in the ATC system. This provided a means by which system design goals could be established. First, a comprehensive review was made of current ATC procedures and the techniques used for issuing and acknowledging clearances; this activity became the basis of an exhaustive ATC message set. Then the message set was reviewed to organize it according to an operationally meaningful taxonomy. Each message was examined on such dimensions as its time criticality, the phase of flight in which it would likely be issued, and the extent to which it implied a change in the operating agreements between the pilot and the controller. It was considered that this type of organization would prove useful in the later stages of developing the concept, where several of these messages would be accommodated on the more structured digital medium. Finally, a scenario was constructed to illustrate the voice communications process in an operational context. A tabulation was made of all communications during the course of a hypothetical flight and enabled message exchanges to be considered from a time-sequenced perspective. This proved helpful in further establishing some of the design goals of the d/l system, as several characteristics of ATC communications become more apparent in this context.

2.1 Generation of ATC Message Set

Even though r/t communications affords participants wide latitude in the manner in which they converse with one another, standard phraseology has been adopted by the ATC system over the years to ensure a more complete understanding between airspace users and the ATC system. In the case where radio reception is poor or broken, for example, the receiving party can still make partial sense of a message if it is issued by the sender according to a commonly-accepted format. In addition, if the message is complicated or contains a high amount of information, the issuance and receiving of the message is made easier by using an agreed-to format. The establishment of standard formats, therefore, enables r/t to be used more efficiently and accurately than if the senders and receivers used random formats, and the FAA has incorporated sets of standard phraseology in pilot and controller manuals and handbooks. (References 19, 20, 21).

A thorough review of these references was made in an effort to develop a comprehensive and fairly exhaustive ATC message set. Special attention was paid to the information content and the ultimate intent of each message. It was not expected that every type of message which may currently be exchanged on r/t would also be appropriate for d/l; in fact, of all the types of messages in the set only a small portion appear to be suitable for d/l. However, to ensure that all potential applications of d/l were considered, all messages for which standard formats were established were included in the development of the ATC message set. The message set resulting from this activity is provided in Appendix C.

2.2 Taxonomy of ATC Messages

A subsequent step in the analysis of the voice communications process was to organize the set of ATC messages into an operationally meaningful taxonomy, or classification system. Each message in the set was reviewed on the basis of its information content, time criticality, and the extent to which a change in operating behavior was expressed or implied. This type of exercise is usually a beneficial initial step in working loosely organized material into the regimented structure needed for d/l consideration, particularly with regard to the additional I/O considerations associated with d/l. If, for instance, the process by which a user composes a d/l message is a "menu-driven" process, then the taxonomy can be used to form the levels (major selections, subchoices, etc.) of the menu. The taxonomy would also serve a useful purpose even if another type of I/O concept was used. If a set of standard message templates were used to create messages, whereby a user fills in the blanks of an otherwise complete message, the taxonomy could be used to condense the set of all possible messages down to a few basic ones. These principles are valid regardless of the actual physical form the I/O device takes (e.g., touch-panel display, line select, artificial speech recognition and generation, etc.)

An additional reason for working the ATC message set into a taxonomy is that the operational procedures and protocols for exchanging various types of messages with r/t can be distinctly different. The cadence of the exchanges which take place when a pilot requests and receives weather information from the ground, for example, is markedly different from those which take place when the controller issues heading instructions or traffic advisories. So in addition to I/O considerations, the development of a taxonomy is useful from the standpoint of developing communications procedures for d/l.

This effort to organize the ATC message set along the aforementioned dimensions resulted in three major categories of information exchanges which were named non-control, strategic, and tactical information exchanges. The message set was broken down further into subcategories within each major category, as shown in Table 2-1 and described in more detail below.

2.2.1 Non-Control Information Messages

The title of this type of message implies that it is intended for information purposes only, and that no change in operating behavior on the part of the pilot or controller is expressed or implied. The sending party issues this type of message (either without prompting or upon request) for the receiver's benefit in planning his future actions and to reduce uncertainty about his state of affairs. They are generally not time-critical, as their value is not appreciably degraded by short interruptions in their delivery. (Related messages having more urgent time-critical characteristics are discussed further below).

Messages in this category fall into three major subcategories, namely: 1) weather-related observations and forecasts, 2) reports on the status of facilities and equipment, and 3) routine reports such as position reports and the provision of estimated times of arrival, etc. Although, as one would expect, the majority of non-control information transfers are generally "upward" in nature (i.e., transmitted from the ground to the air in response to pilot requests for such information), there are also numerous cases where the aircraft provides similar information for the benefit of the ground personnel. Provision of observed, in-flight weather conditions, for example, enables controllers and flight service specialists to determine if observed conditions are consistent with recent forecasts and also if changes in the forecast and the current flow of traffic are appropriate.

In some instances the issuance of non-control information has become automated. Automatic Terminal Information Service (ATIS) and Transcribed Weather Broadcasts (TWEB) are examples in which recorded information is repetitively broadcast on an assigned r/t frequency, thereby relieving a human of the chore of continually repeating this information on request. Receiving the information, however, still requires the pilot to devote cognitive effort to the process of understanding and recording pertinent data.

TABLE 2-1
ORGANIZATION OF ATC INFORMATION EXCHANGES

MAJOR CATEGORIES	NON-CONTROL INFORMATION	STRATEGIC	TACTICAL
CHARACTERISTICS	• Planning/Information purposes only • Do not imply change in operating behavior • Generally not time-critical • Follow either "Request/Reply" format or information provided on unsolicited basis	• Relate to overall objectives of flight • Usually initiated by pilot; revised by controller or pilot. • Somewhat time-critical; not overly so • Conducted with intent of establishing overall operative agreement between pilot and controller	• Relate to situation of local nature • Do not alter strategic agreements; may fill-in unspecified details • Can be very time critical
EXAMPLES	– Weather observations & forecasts – Facility & equipment status reports – Routine progress reports	– Initial flight plan submission and IFR clearance – Revision to established IFR clearance	– Horizontal, Vertical, or Speed/Time/Delay (HVS) instructions – Procedure-based instructions – Comm/Surveillance instructions – Traffic & Urgent advisories.

2.2.2 Strategic Messages

The next major category of messages are strategic messages, which are concerned with the overall mission of the flight. Through the exchange of strategic messages the airspace user and the ATC system can specify what their basic objectives are, and can agree in principle to the actions they will take in support of one another's objectives. In the civil aviation environment, the process of reaching a strategic agreement is usually initiated by the pilot when he submits a proposed flight plan to the ATC system. During the course of a flight, revisions to an established strategic agreement may be requested by the pilot or the controller when circumstances require a change in the way the objectives are met, or when a change is made in the objectives themselves. Strategic messages are generally more time-critical than non-control messages, but are not overly sensitive to modest delays in their transmission and receipt.

Strategic messages fall into two major subcategories: those associated with reaching an initial agreement, and those associated with revisions to previously-made agreements. Messages which are used to reach an initial agreement include the flight plan submitted by the user and the corresponding clearance issued by the ATC system. Although the flight plan is usually submitted in advance of the proposed flight, it could be submitted by the pilot using r/t while the aircraft is on the ground or in-flight. A standard format is specified for the flight plan on which the pilot can indicate the overall objectives for his flight (destination, route, altitude, departure time, etc.), pertinent aircraft equipment (in terms of transponder and navigation capability), and other information which, although it does not further describe what the flight intends to do, is convenient to collect at the time the flight plan is submitted (such as pilot name and address, fuel on board, and other search-and-rescue (SAR) data).

Unlike the simple request-reply nature of non-control information exchanges, the pilot must obtain a clearance from ATC before entering controlled airspace under Instrument Flight Rules (IFR). Therefore, the process of reaching a strategic agreement requires a series of exchanges. After consideration of the aircraft's proposed flight in light of other traffic and environmental conditions, the ATC system responds with an initial ATC clearance which authorizes the user to "enter" the system under IFR, and specifies a complete course of action to the destination, or to an interim point with additional instructions on what to expect at the interim point.

To the extent it can, the ATC system tries to issue a clearance exactly as the user requested in the flight plan, or come as close to it as possible. If the user accepts the clearance, it becomes the operative strategic agreement between the pilot and controller for the duration of the flight or until it is later modified. If the clearance does not immediately match the user's preferences, he may negotiate with the ATC system to obtain an acceptable clearance, or he may accept the clearance in hopes of getting it modified to a more suitable form later, or he may drop his request to participate as IFR traffic in the ATC system. In any case, the pilot and controller reach a strategic agreement through the process of filing a proposed flight plan and subsequently agreeing on an ATC clearance.

Sometimes during the course of a flight, the user or the ATC system may find it necessary to alter a strategic agreement which is already in place. In this case, the pilot or controller need only specify the parts of the current agreement which need to be changed and upon acceptance by the other party the revised portions become the new operative strategic agreement.

2.2.3 Tactical Messages

The third major category of messages are called tactical messages and include those control messages relating to a situation of a local nature in terms of space or time. Whereas the strategic agreement establishes the overall objectives of a flight and a game plan to achieve those objectives, various tactical agreements are established more frequently throughout the flight to address short-term conditions. Tactical agreements do not change an established strategic agreement, but they may fill in the unspecified details of a strategic agreement. Because they pertain to local events or conditions, tactical messages can be very time-critical.

There are four major subcategories of tactical messages, namely: 1) horizontal, vertical, or speed/time/delay instructions (HVS), 2) procedure-based instructions, 3) communications/surveillance instructions, and 4) traffic and urgent advisories. HVS messages are issued to specify how the flight is to be conducted in the horizontal and vertical planes, as well as how to manage the forward progress of the flight through speed/time/delay instructions. Horizontal instructions may come in the form of assigned headings (e.g., radar vectors) or be specified in reference to navigation facilities. Altitude messages indicate in numerous ways how and when the aircraft should climb to, descend to, or maintain a given altitude. Speed/time/delay instructions include speed commands, crossing-time instructions, and delay maneuvers such as S-turns, 360° turns, or execution of a holding pattern. HVS messages are usually issued by ATC and will include the local reason for issuing the messages. However, the pilot may also issue an HVS request to address a local condition, such as to avoid weather associated with turbulence.

Procedure-based instructions include those in which the management of the aircraft's course, altitude, and speed are described in an approved, published procedure. Primary examples are instrument approach procedures (IAPs), standard terminal arrival routes (STARs), and standard instrument departures (SIDs). When such a tactical agreement is reached the aircraft is expected to perform the procedure as specified, unless certain modifications are appended to the agreement.

Communications and surveillance messages include those exchanged to maintain appropriate radio and radar contact between the aircraft and ATC facilities. Examples of the surveillance messages are instructions to squawk a unique transponder code or to turn to assigned headings for radar identification purposes.

The final subcategory of tactical messages are those associated with traffic and urgent advisories, such as windshear alerts. Unlike HVS, procedure-based, and communications/surveillance messages, traffic and urgent advisory messages do not specify the manner in which the aircraft is to be operated. However, they are included in the tactical message category because of their time criticality and because the local condition causing the advisory requires caution and may require quick action.

2.3 Development of a Radiotelephone Communications Scenario

To gain a greater appreciation for several operational factors associated with r/t communications in the ATC system, a scenario was developed in which common ATC message exchanges were placed in an "operational" context. In actual practice the flow of ATC communications is influenced by preceding events and information exchanges, as well as by the stated objectives of the user as contained in the strategic agreement. Therefore, the analysis of information exchanges in their historical, time-sequenced context is as important as looking at isolated exchanges themselves. The r/t communications scenario, then, served as a stage on which the communications process could be studied in a simulated, operational context.

The scenario described in this section, and presented in its entirety in Appendix A, includes those voice communications which can be reasonably expected during the course of an average flight. While the scenario is not a verbatim transcript of a flight which actually took place, many elements such as the schedule, flight plan, and route are predicated on a flight performed by a major air carrier DC-10 aircraft from Boston-Logan Airport (BOS) to Chicago-O'Hare Airport (ORD) to Denver-Stapleton Airport (DEN). The routes and communication transactions were selected on the basis of their value as an illustrative and investigative aid of the voice communications process, as well as the need for them to be accommodated in a future communications system augmented by d/l.

Several resources were used in making up this scenario. First, the Air Traffic Controller's Handbook (Reference 19) and the Airman's Information Manual (Reference 21) were used extensively to ensure that ATC procedures and phraseology were consistent with government-approved practices and regulations. In addition a report by Berry (Reference 22) was consulted in which the cockpit workload impact from four new cockpit systems was assessed on a hypothetical flight. The report included a time-based script of aircrew activities during the course of an air carrier flight and how those activities might be influenced as the new cockpit technologies are introduced.

Additionally, various participants in the aviation community such as pilots, air carrier flight planning and dispatch personnel, and air traffic controllers were contacted to provide a real-world dimension to the scenario. Conversations with such individuals provided additional insight into the strategies employed by users and the ATC system in reaching their objectives. They also revealed common operating practices of pilots and controllers which are not documented or described in an official publication, but are widely applied in day-to-day operations.

Even though the communications presented in this scenario are from the perspective of an airline cockpit, they are just as applicable for operations involving general aviation, business, or military aircraft. While there are different levels of sophistication in the collection of preflight data and the preparation and submittal of flight plans for these users, there is not much difference between them in terms of the communications procedures they apply in the ATC system once a flight plan has been submitted and a clearance obtained for IFR flight.

2.3.1 Preflight Planning Strategies and Assumptions

The flight identifier used for this hypothetical scheduled air carrier operation is Transair 297 (TA297), and published operating timetables call for the following departure and arrival times:

Depart	BOS	1610 (EDT*)	2010 (UCT*)
Arrive	ORD	1738 (CDT)	2238 (UCT)
Depart	ORD	1844 (CDT)	2344 (UCT)
Arrive	DEN	2014 (MDT)	0214 (UCT)

For most airlines, planning the specifics of a flight such as this for a given day is the responsibility of a central company dispatch facility, which maintains direct links with a number of computerized databases, including those in the National Weather Service, FAA Air Route Traffic Control Centers, plus company maintenance and scheduling computers. As the time for scheduled departure of the flight approaches, the dispatch facility solicits and collects available information on factors that will affect the flight, such as reported and forecast winds aloft, known flight delays, projected aircraft weights, and any limitations or special considerations which might apply to the flight as a result of inoperative airborne or ground equipment. After considering these data, the dispatch facility prepares a flight plan which specifies a desired route and altitude, estimated groundspeeds and times en route, fuel consumption between significant points on the route, and alternate airports if weather conditions at the destination require the designation of an alternate.

The actual preparation of the flight plan for most airline dispatch centers is largely an automated process in which the flight dispatcher specifies the limitations imposed on a flight which are then combined with other data by the dispatch computer. To arrive at a flight plan that reflects the minimum cost for that particular flight (in terms of fuel consumption, labor, maintenance, etc.), the dispatch facility usually considers a number of route/altitude combinations for the flight, and selects the combination which minimizes its cost.

* Airline departure and arrival timetables are published with respect to local time; however internal airline operations are usually referenced to Coordinated Universal Time (UCT, formerly called Greenwich Mean Time (GMT) or Zulu Time). In this report the terms Zulu, GMT, and UCT are used interchangeably.

On occasion, a route other than the minimum cost route is selected to avoid marginal weather, turbulence, or traffic congestion. In any case, the selected route and altitude along with other descriptive data are submitted to the ATC system as a proposed flight plan. This could be performed by a direct computer-to-computer link with ARTCC computers or via telephone, and constitutes the first message exchanged with the intent of reaching a strategic agreement.

When the flight plan is filed, it is first checked by ATC computers for completeness and for compatibility with the ATC system. Gross errors or aspects which the computer cannot understand are flagged, and the associated flight plan is rejected. If an ATC-preferred route* is active between the city pair, the computer automatically amends the route to conform to the ATC-preferred route. For illustrative purposes it was assumed that the flight would be cleared on an amended route (i.e., not according to the desired route indicated in TA297's proposed flight plan).

Even though the availability of computerized databases and direct links to access them enables many users, primarily airlines, to automate a major share of flight planning functions, it is not necessary to assume that such automation is required to make d/l feasible or desirable. Other users, such as general aviation or small airlines, still perform these functions manually. However, it is not usually possible to consider as many different route/altitude combinations to find an optimum for a given objective (such as minimizing fuel consumption, total operating cost, or time en route). In any case, flight planning activities only set the stage for future communications between ATC and the user, and the description presented here is intended to show the opening negotiating positions of the user and the ATC system. Regardless of the sophistication of the flight planning process, the same basic format of information is used to submit the plan to the ATC system.

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* ATC-preferred routes are routes established by the FAA along highly travelled corridors between major city pairs. They are usually established to coordinate the flow of traffic and also to facilitate coordination between affected ground facilities for the generation of flight clearances. They may be active only during peak travel hours, or for the entire day.

A brief synopsis of the BOS-ORD portion of the scenario is presented below, while the complete scenario is provided in Appendix A. Excerpts from the scenario are given to make points about the voice communications process, and a commentary and summary is provided in Section 2.4.

2.3.2 Assumed Route and Flight Profile

The major parts of the flight plan as filed, and as subsequently flown, by TA297 are depicted in Figure 2-1 for the BOS-ORD segment. In addition to depicting the major navigation fixes and the crossing times along TA297's route, Figure 2-1 also shows the ARTCC boundaries for facilities which will have jurisdiction over this flight at some point. In addition to contacting new ARTCCs as these boundaries are crossed, TA297 will frequently have to contact new sectors within a given facility during the course of the flight.

At approximately 1:30 hours prior to scheduled gate departure, the TA company dispatch facility prepares a flight plan forecast, a weather briefing, and a dispatch release message and forwards these to BOS for the crew via teletype. The flight plan forecast contains pertinent information such as the flight plan as filed with ATC, a flight log showing fuel burns and ETEs, and comparative cost summaries for flight at the filed altitude and nearby altitudes. After completing other preflight planning and aircraft preparation duties, the flight crew members enter the cockpit and get ready for flight, at which point the time-based script begins.

After acquiring the local BOS airport conditions through the ATIS message, the crew contacts BOS Clearance Delivery to obtain and review the ATC clearance to ORD. This exchange of messages is shown in Table 2-2.

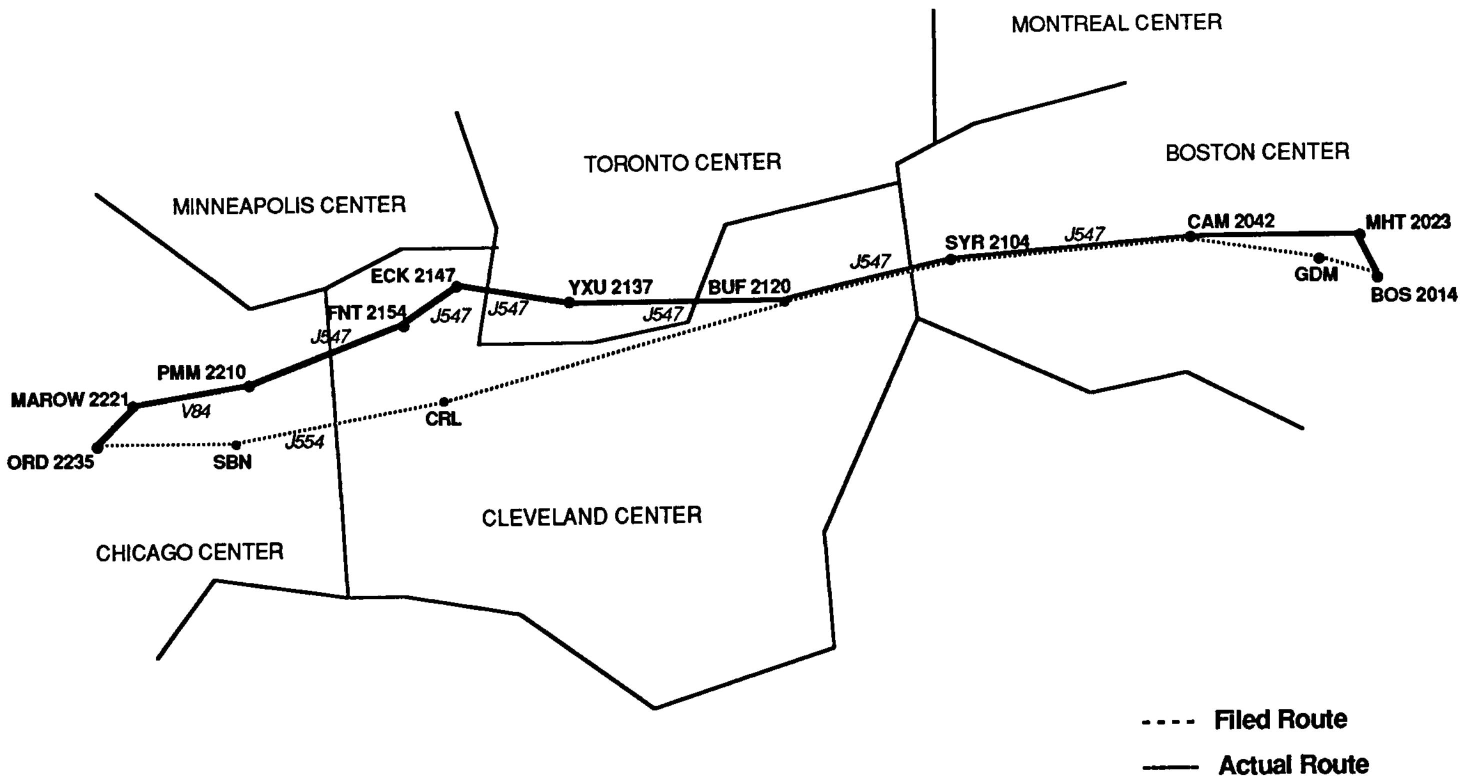

FIGURE 2-1
FILED AND ACTUAL ROUTE FOR TA297 BOS - ORD

TABLE 2-2
RADIOTELEPHONE EXCHANGE FOR ACQUISITION
OF IFR CLEARANCE

TIME (GMT)	AG/ GA*	INFORMATION CONTENT	REMARKS AND USAGE
		Request for Clearance	
2005	AG	"BOSTON CLEARANCE, TRANSAIR 297 HEAVY, GATE 5 WITH ATIS HOTEL, READY FOR CLEARANCE TO CHICAGO."	• Indicates crew prepared to copy down clearance, and has latest airport conditions.
	GA	"TRANSAIR 297 HEAVY, BOSTON CLEARANCE, YOU ARE CLEARED TO CHICAGO-O'HARE VIA LOGAN3 DEPARTURE TO MANCHESTER DIRECT CAMBRIDGE J547 PULLMAN V84 MARROW DIRECT MAINTAIN FLIGHT LEVEL 390, DEPARTURE FREQUENCY 127.2, SQUAWK 4614."	• Indicates aircraft id (including transponder code), clearance limit, route, altitude, and future communications.
	AG	"CLEARANCE TRANSAIR 297 HEAVY WILL HAVE TO CHECK THAT ROUTING, STANDBY."	• Because this is not the route that TA297 filed and is prepared to fly, the crew must review it to determine if it is still acceptable. It will be assumed to be acceptable, although the crew may seek modifications once airborne.
	AG	"TRANSAIR 297 HEAVY CLEARED TO CHICAGO VIA LOGAN3 DEPARTURE TO MANCHESTER DIRECT CAMBRIDGE J547 PULLMAN V84 MARROW DIRECT MAINTAIN FLIGHT LEVEL 390, 127.2, 4614."	• Readback by crew ensures clearance copied and understood correctly, signifies acceptance of clearance if not stated otherwise.
	GA	"TRANSAIR 297 HEAVY, READBACK IS CORRECT, EXPECT NO TAKEOFF DELAYS, CONTACT GROUND 121.9 WHEN READY TO PUSH BACK."	• States readback is correct (if so), states delay and future communication instructions.
	AG	"TRANSAIR 297 HEAVY (ROGER)"	• Indicates TA297 got last message. Signs off this frequency.

*AG = Air to Ground, GA = Ground to Air

2.4 Major Observations of the Radiotelephone Communications Process

The placement of various types of exchanges in the operational context of the r/t scenario illustrates several desirable and non-desirable characteristics of the voice communications process. First, the I/O tasks associated with assembling information and formatting it according to recommended phraseology are very simple. Because the message sender and the message receiver have a shared code (namely the English language), and because the information is conveyed in the context of spoken words and numbers, it is not necessary for issued or received messages to be translated in any way (e.g., into strings of bits). In addition, the flexibility of free-form language to express a message in many different ways enables understanding to be reached between pilot and controller for an unlimited number of situations. Even in the presence of recommended standard phraseology, if a message is not clear or understood, the sender and receiver can break away from recommended formats and develop their own communications protocols until an understanding is reached. There are also many ways in which the intent of the same verbal message may be altered by voice inflection. Depending on inflection, the same message could be treated as a statement of fact or as a question.

Another desirable characteristic of voice communications is that humans are in-the-loop of all air/ground message exchanges. Because the voice communications process requires human sensory and cognitive abilities to generate or decode them, voice messages cannot bypass the human. While this may have an undesirable effect in terms of workload, it does help to ensure that the human and the machine have the same basic set of information. Having the human in the loop of all messages also enables him to combine information and determine its relative merit and pertinence. The value assigned to a received message is influenced by information the receiver already has, and involving the human in all message exchanges only serves to broaden this set of information.

Because he is actively engaged in all inbound and outbound communications, the human is also frequently apprised of the status of his r/t equipment, procedures, and his communications partner. Nearly all transactions require an acknowledgement of receipt of message to be issued by the receiving party back to the sending party. In this way the sender can know that the proper person received the correct information. Any interruption to this round-trip closure becomes readily apparent to the sender, who can then try to reissue the message or try to determine which part of the process is at fault. In a sense, every message exchange is a test of the continuity of the entire communications loop. Because he is involved in every message exchange the human is a constant monitor of his r/t status. There are times when failures of the communications loop may go unnoticed for a period of time (such as during low activity periods when there is not much voice traffic, and therefore the "tests" are not conducted frequently); however, a degradation of r/t communications capability becomes readily apparent on an active frequency.

A final major desirable characteristic of r/t communications is that the procedures to support message exchanges are consistent for all types of messages. All of them basically follow the transmission/acknowledgement format, and are approximately equally tolerant of time delays in the receipt of acknowledgements. In other words, the sender who waits for an acknowledgement will apply approximately the same time allowances (for the receiver to evaluate and transmit an acknowledgement) before suspecting a communications breakdown, regardless of the type of message being sent. As a result, a fairly uniform set of procedures apply to the exchange of all types of messages (e.g., non-control, strategic, or tactical).

There are also several non-desirable characteristics of r/t in ATC communications which offset some of the desirable characteristics mentioned above. First, the human is burdened with many "overhead" tasks in the communications process. This is illustrated in Figures 2-2 and 2-3 which list the functions performed by the pilot for receiving and sending a single r/t message. Several of these functions such as monitoring the voice channel, filtering voice channel traffic for his own aircraft identifier, acknowledging receipt, etc., involve significant amounts of workload, and are not an advantageous use of the pilot's time and abilities.

In addition, the human pilot or controller cannot defer the treatment and disposition of inbound messages. Regardless of the time criticality of a given message, the receiving party must attend to it immediately (i.e., devote resources to receive and decode the information and make the appropriate acknowledgement), or disregard the message and force the sender to issue it again. In either case, additional workload is created because the human cannot schedule his review of those inbound messages that are not overly time critical.

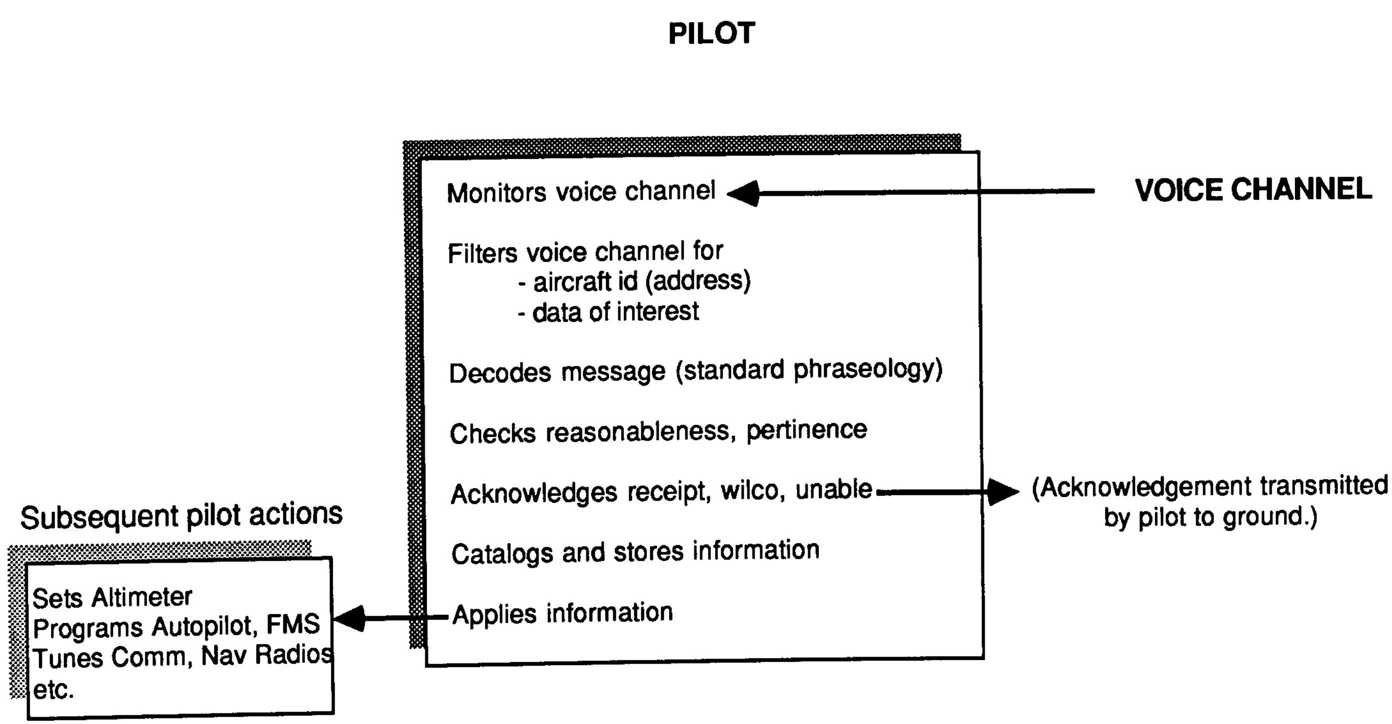

FIGURE 2-2
PILOT FUNCTIONS WHEN RECEIVING R/T MESSAGES

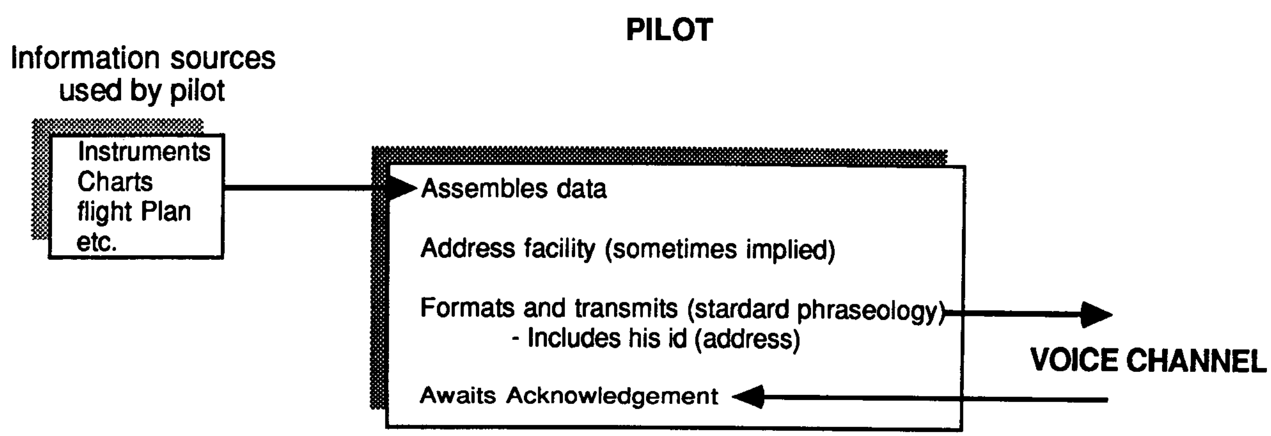

FIGURE 2-3
PILOT FUNCTIONS WHEN TRANSMITTING R/T MESSAGES

A related problem with r/t communications is that the human must catalog and store information, either by memorizing it or by writing it down. This is a problem especially for messages which are complex and lengthy in terms of information content, and also which will be applicable for extended periods of time. A prime example is the ATC full-route clearance issued at the beginning of the flight. In addition to receiving and decoding the message, the pilot must simultaneously write it down to facilitate the readback and to have a durable record of the operative strategic agreement between him and the controller.

Apart from these non-desirable characteristics, the general nature of r/t communications makes it prone to a variety of operational errors. The congestion of r/t frequencies is often a cause for messages to be missed or blocked by other transmissions. On occasion a message is received and acknowledged by the wrong receiver, thereby creating two problems for the ATC system to recover (one is due to intended receiver not performing instructions destined for him and the other is due to the wrong aircraft performing the instruction). These and other types of communications errors have been the subject of several recent studies (Reference 23).

Two other general observations might be made from this review of the r/t communications process in the ATC system. First, once a basic strategic agreement is reached between the pilot and controller, most subsequent messages are simply updates or slight modifications. This is consistent with the general principles of ATC in that the strategic agreement (IFR clearance) specifies an overall game plan. The subsequent, tactical messages are issued as local events dictate, but are still issued with the intent of satisfying the strategic agreement. As a result, ATC communications can be considered as a more or less "continuous" process in that the pilot and controller issue and interpret messages on the basis of information they already know about one another. It is not necessary to respecify elements of a previous agreement which are not going to be changed.

The second observation is that the pilot and controller frequently act as a conduit for inbound messages, and enter the information for an automated system to perform a task. After passing judgment on the appropriateness of a received tactical message (a heading instruction) for instance, the pilot may program the autopilot to make the turn and fly the heading. For some types of non-control messages, he may not be required to even pass judgment on the information. This might be the case when the pilot is issued an altimeter setting and sets the new value into his altimeter system.

3. A SYSTEMS CONCEPT FOR DATA LINK IN ATC COMMUNICATIONS

The major emphasis in this step of the project was to carve out a suitable role for d/l to play in an ATC communications system. This involved the establishment of system design goals based on a review of the observed characteristics of voice communications in Section 2, incorporation of additional features made possible by d/l, and consideration of safeguards to be used when both d/l and r/t are capable of supporting transactions. Even though possible I/O configurations are presented here for illustration purposes, the concept should be considered only at the systems level: there is wide latitude in the physical form that the hardware may take and it is not necessary to specify hardware requirements for the concept to be valid.

3.1 System Design Goals

The establishment of system design goals was perhaps the most important single aspect of this development effort in that it required a clear definition of the desirable performance characteristics of the communications system. Once these goals were established (and, in fact, the roles of d/l and r/t were clarified) it was a fairly straight-forward process to design a system toward those objectives. Several of the design goals outlined below are developed from the observed characteristics previously noted for r/t communication, and others are based on some of the proposed applications of d/l as well as the need to incorporate procedural and system safeguards for potential errors.

3.1.1 Keeping Input/Output Tasks Simple

As mentioned in Section 2, r/t communications do not require excessive effort to compose and deliver messages, and, although receiving and interpreting may be a bit more difficult than sending, this also does not require undue effort. Therefore, in order for d/l to be successfully used alongside r/t in the ATC environment, the I/O workload associated with d/l should be comparable to that associated with r/t.

3.1.2 Keeping Humans and Machines in Common Information Update Loops

Several proposed applications of d/l involve somewhat direct computer-to-computer communications, such as the transmission of a complex, 3-dimensional path assignment from an ATC computer to an airborne computer. These types of data exchange could not be considered possible without the presence of d/l and the computers required to process the information. However, there is a need to ensure that the humans at each end of the link are apprised of information being exchanged on the link. Otherwise, the pilot or controller cannot effectively manage their respective systems because they do not know the other inputs on which their systems are acting.

3.1.3 Providing Detection and Notification of Communications Interruptions

Current r/t procedures and characteristics usually enable the pilot or controller to become readily aware of a communications failure, but the basic characteristics of d/l communications may not provide an equivalent level of failure detection capability. Due to the discrete addressing feature of candidate d/ls, the aircraft will be receiving and decoding only those messages intended for it, rather than being a participant in the "party line" associated with r/t. As a result, the airborne system, including the pilot, will receive fewer messages and there will be longer periods of silence between messages. This characteristic tends to mask the occurrence of a d/l communications failure as it is more difficult to determine if a period of silence is failure-related or just an unusually long period of d/l inactivity.

There may also be periods of scheduled interruptions to d/l services which are not associated with a failure of the link or related components. An example would be flying into an area where d/l coverage does not exist and it is known in advance that the aircraft will be transitting this airspace. In cases such as this, the system should still provide a clear indication of the operational status of the link and its availability for use in exchanging various kinds of messages. It should also incorporate safeguards to prevent its use when it is known that d/l cannot support a message exchange at a given geographic location.

3.1.4 Maintaining Procedural Consistency for Various Modes of Communication

The presence of both r/t and d/l gives rise to two "modes" of communication between the pilot and controller, namely r/t-only, r/t and d/l. To the greatest extent possible, the communications procedures used for these modes should be similar. This would make the system easier to use, as an operator would not have to know several procedures to accomplish the same objective. It would also reduce the likelihood of errors arising from the use of a procedure which was not appropriate for the mode.

3.1.5 Off-Loading of Overhead Communications Tasks

A large portion of the workload associated with sending or receiving r/t messages is due to the overhead functions the human must perform such as monitoring the frequency, filtering the radio chatter for his address, cataloging and storing, etc. However, messages exchanged on d/l are in a form suitable for the machine to perform these functions. As a result, the management of d/l communications can be made considerably easier by having the system attend to the chores that the human need not perform. The human, then, has more time and resources to devote to tasks he is uniquely qualified and motivated to perform, such as checking the reasonableness and pertinence of received messages, determining their relationship with regard to his current situation, and making the appropriate response.

3.1.6 Buffering Messages When Desirable

As described in Section 2, when r/t messages are sent they require the receiving party to interrupt ongoing tasks and devote full cognitive effort to listening to the message and initiating a response. However, while there are a few messages that deserve such attention, the majority of messages can be treated in a more casual fashion. Messages which are not time-critical, such as strategic or non-control information messages, do not usually require an immediate response. If a buffering mechanism, or an "in basket," were established for messages such as these, the pilot could schedule his review of the information at his convenience. The pilot, in effect, is given the opportunity to schedule his tasks to redistribute his workload more evenly.

This design goal is considered especially desirable from the standpoint of the use of the pilot's eyes. In the current r/t environment, audio messages do not compete for the pilot's visual scan of his instruments, charts, and especially his scan for other air traffic. Several possible d/l I/O configurations, however, would require him to read the messages from a cockpit display, thereby interrupting his scan of more time-critical information. A buffering capability would resolve this conflict in that the pilot can work the message reading process into his visual scan when convenient.

3.1.7 Establishing a Means of Preserving Information

A major activity of the pilot in r/t communications involves retaining information for future use, either by memorizing it or by writing it down. However, d/1 messages are in a form which could be stored by the machine and routed by the pilot to other parts of the airborne system. This feature would relieve the pilot of record-keeping tasks and would allow him to review earlier messages to confirm current ATC assignments and agreements. Retaining information in a storage area also makes it available for use by other parts of the airborne system (such as the flight management system (FMS)) for appropriately configured aircraft. This would reduce the need for the pilot to act as an information transfer medium in reprogramming the autopilot, for instance, on the basis of a received ATC heading instruction.

3.2 Description of A Data Link Systems Concept

The development of a d/1 systems concept involved merging the functions required in the communications process with the system design goals mentioned above. Tasks were logically allocated to the machine and/or the human in an effort to satisfy the system design goals. The resulting concept was reviewed and refined to incorporate improvements suggested by others with different perspectives, and was also analyzed, in part, by exercising it in a data link version of the same scenario used to analyze r/t communications.

The description of the systems concept in this section is presented from the standpoint of the aircraft cockpit. The concept itself can be applied in a wide variety of airborne environments (such as single-pilot general aviation or multi-crew air transport aircraft) with equal ease. The scenario which illustrates the application of the concept in Appendix B is presented with regard to how an airline crew might use the system. It should also be kept in mind that this systems concept describes an allocation of functions and procedures primarily to support communications between the aircraft and the ground. There are many provisions in the concept for additional uses of the information once it has been passed from air to ground, or vice versa. Although only the airborne view is presented here, a very similar concept can be developed for the task allocation and procedures needed for the ground-side of data communications.

3.2.1 Communications Management System

The center of this system concept is the Communications Management System (CMS) which the pilot uses as an aid in both r/t and d/l communication. It assists the pilot in the generation and sending of outbound messages, as well as the receiving, decoding, and disposing of inbound messages. It also provides a bridge between communications performed on d/l and those performed on r/t. In order to facilitate an understanding of this communications system concept, the following description of the CMS focuses on the functions it performs rather than on the hardware or system architecture. In fact, the CMS does not necessarily represent a new "box" for the cockpit but may instead be considered as an organization of communications functions which need to be performed to communicate with d/l. System designers could elect to distribute these functions among other on-board computers (such as an FMS, engine information and crew alerting system (EICAS), etc.), or may elect to have these functions performed by a dedicated processor. In any case, this description of the CMS functions and its responses to various inputs and outputs provides a comprehensive definition of how d/l may be used to advantage in the future ATC environment.

The CMS, itself, is comprised of the four main components shown in Figure 3-1, namely: a message handler, a buffer, pilot I/O interfaces, and a storage area knows as the Airborne Message File. Within these four components, all of the tasks associated with r/t or d/l communications are performed automatically or by the pilot in those cases where he is best suited to perform a function. As for the overall description of the CMS, the term "component" refers to a set of related functions which may be performed by one or more devices in the airborne system, and does not imply that all of the related functions must be performed by the same single piece of avionics hardware.

The <u>message handler</u> is the main "front-end" component, which performs all of the overhead tasks associated with d/l transactions as listed in Figure 3-2. These tasks are usually included as part of the lower layers of the OSI reference model. The main functions of the message handler can be sorted into those associated with receiving and those associated with sending messages. Receiving functions include monitoring the links for which the aircraft is capable of data exchange; recognizing its address and messages intended for it; decoding the messages and checking for errors; acknowledging receipt of messages or asking for retransmission; and routing the

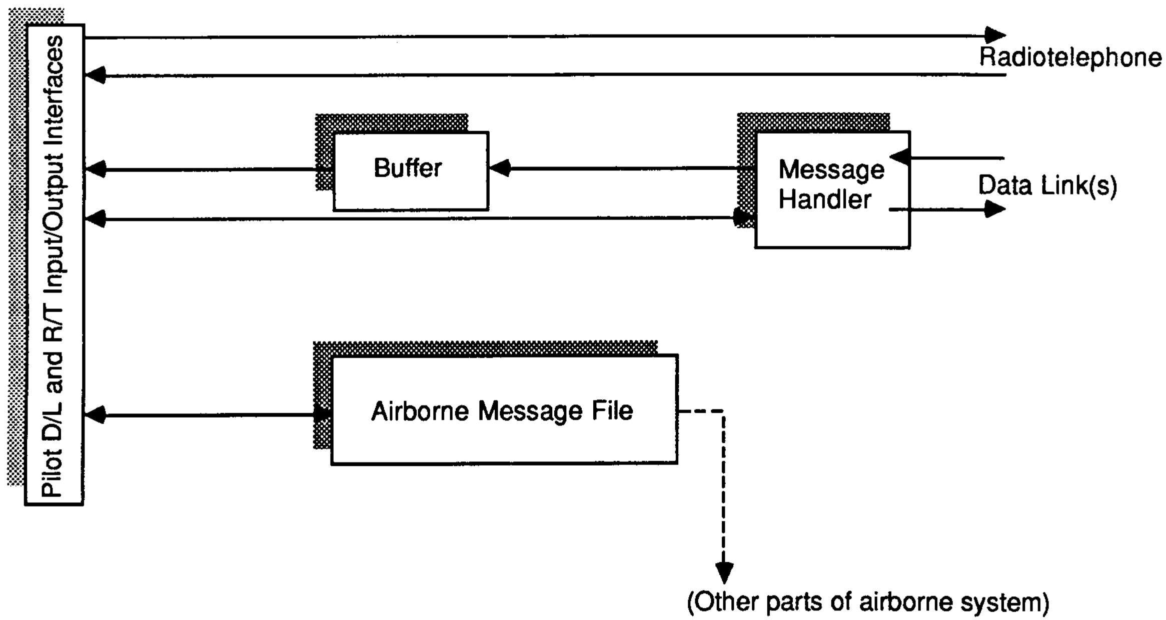

FIGURE 3-1
MAIN COMPONENTS OF COMMUNICATIONS MANAGEMENT SYSTEM

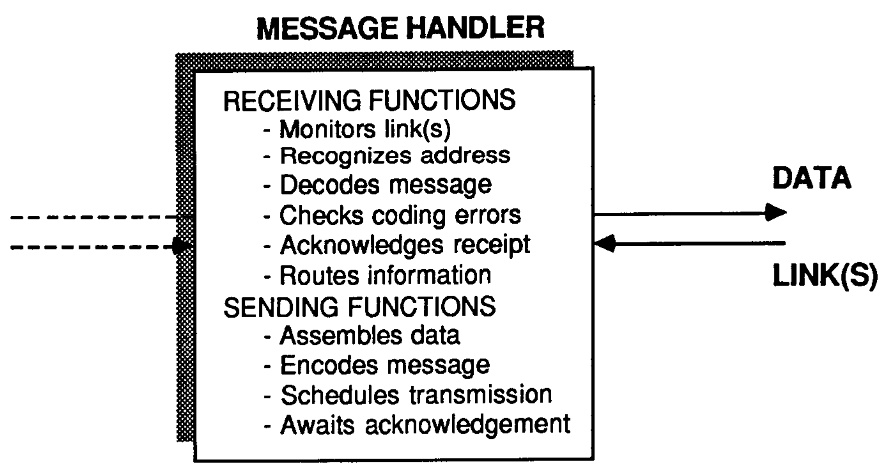

FIGURE 3-2
MESSAGE HANDLER FUNCTIONS

information to the appropriate airborne element. In performing these functions the message handler also performs the bookkeeping that might be required to keep track of received messages and their final disposition.

Sending functions include assembling the data from the pilot to construct a message; encoding the message; scheduling and transmitting the message on the appropriate link; and awaiting acknowledgement of receipt from the intended destination. The sending functions also require the message handler to keep track of sent messages for appropriate acknowledgements and responses, and to re-attempt transmissions when no acknowledgements are received from the ground system.

It should be noted that, because the aircraft may be equipped to conduct data exchanges on more than one link, the message handler also performs the executive functions of selecting the appropriate link for dispatching an outbound message, and simultaneously monitoring all the links for inbound messages. Potential airborne configurations for airline cockpits, for example, could include Mode S, ACARS, and perhaps a satellite-based link. Integrating these links into a single communications system would relieve the pilot of the task of selecting the appropriate link for a given message and would simplify the architecture of the airborne system. Such integration would make the actual link supporting a transaction transparent to the pilot, and he would only need to be concerned with the information content rather than the mechanism used for a message's exchange.

The buffer is simply a temporary storage area for appropriate inbound messages. In hardware implementation it could be designed as part of the message handler, or some other component, but its function is distinct and warrants separate discussion. Inbound messages which are not of a time-critical nature would be directed to the buffer by the message handler. An appropriate notice would be issued to the pilot that a message has been received and is waiting in the buffer for review and disposition at his convenience. The pilot would gain access to the information through his I/O interface described below. Not all inbound messages are appropriate for such buffering, however, so the message handler can bypass the buffer to bring more urgent messages to the direct attention of the pilot.

The pilot interface is the set of devices through which the pilot performs two major tasks: 1) issuing and receiving messages and 2) transferring messages and information between various parts of his airborne system. The interface includes those devices which are expressly designed and used for digital data, those which are associated with r/t communications, and those whose functions change according to the primary mode of communications in effect between the cockpit and the ATC system (i.e. whether r/t is the primary mode, or d/l is the primary mode). It is not necessary to further describe the detailed physical form these devices may take as there are several technologies now in use, or under development, which could satisfy requirements. For example, standard navigational control/display units (CDU's), touch-panel cathode ray tubes (CRTs), printers, speech synthesizers, etc. may be used by the pilot to perform part of all of the first task mentioned above. The emphasis of this system-level description of the airborne system with regard to interfaces is on the information presented to, or generated by, the pilot and the means by which the information gets shipped around to other parts of the airborne system.

In the performance of the second task mentioned above, namely to transfer information between various parts of the airborne system, the pilot and the interface may jointly be considered as a "data bus." The interface hardware itself would perform the transfers according to the executive decisions made by the pilot. As will be described later, this is the primary means by which the pilot is kept in the loop of digital data exchanges.

The Airborne Message File (AMF) performs a number of roles in communications between the air and ground systems. Its primary function is to serve as a repository of d/l messages received by the aircraft. It is also used as a reference for the generation of messages to be issued by the pilot to the ground facilities. The AMF relieves the pilot of the chores of cataloging and storing information and in most instances obviates the need to manually copy information.

To facilitate an understanding of how the CMS treats inbound messages and aids in the generation of outbound messages, the storage area of the AMF may be partitioned in the two dimensions as shown in Figure 3-3. It may first be divided into columns for the three types of messages discussed in Section 2, namely those associated with non-control information exchanges, strategic exchanges, and tactical exchanges. It can also be divided into rows on the basis of whether the data are subject to revision during the course of a flight (dynamic) or whether they remain constant once specified at the beginning of a flight (static). As for other components of the CMS, this

AIRBORNE MESSAGE FILE

	NON-CONTROL INFORMATION	STRATEGIC	TACTICAL
DYNAMIC DATA	Weather reports, forecasts, NOTAMs, etc.	Most recent IFR clearance as received from ATC	Most recent tactical instructions such as speed, altitude, heading commands; procedure commands; comm/surveillance commands
STATIC DATA	Weather station identifiers inserted by pilot	Filed flight plan inserted by the pilot (includes flight identification, departure point and time, route, altitude, speed, destination etc.)	NOT USED

FIGURE 3-3
PARTITIONING OF AIRBORNE MESSAGE FILE

partitioned conceptualization of the AMF is intended only to aid in the visualization of its processing of messages, and does not imply that these functions must be carried out by a single processor or prevent the distribution of these storage areas among related parts of the airborne system.

The establishment of both the static and dynamic areas of the AMF enables the CMS to capitalize on one of the observed characteristics of ATC under r/t procedures; that is that most communications involve updates to information received or established earlier in the flight. The provision of an initial, static portion of the AMF enables the pilot to specify in advance those things which will continually be of interest to him during the course of the flight, and for which he will likely request information, such as the weather at the destination. In addition, the static portion of the AMF also includes those parts of the flight plan (as submitted to the ATC system) which will make the user and his objective unique to the ATC system. This includes, for example, the aircraft's flight identification (the r/t call sign), aircraft type, departure point and time, route, altitude, destination and alternates. Maintaining this information in the AMF makes the generation of messages by the pilot easier in that he is required only to "call-out" from the AMF the pieces for which he would like more information through the data link, rather than having to engage in a cumbersome input process such as a series of keystrokes. The CMS can also automate much of the message generation process by simply referring to the AMF static data to formulate a data link message on the pilot's command. In summary, then, the static portion of the AMF includes those data with which the pilot can initiate data link conversations either at the beginning of the flight or during the course of the flight.

It should be recalled that tactical messages, which are more time critical, relate to a local situation or event. As a result, there is little which can be specified in advance about tactical information for a given flight and, therefore, the static portion of the AMF for tactical messages is not used.

There are several possible methods by which the pilot could insert static data into the AMF. Airborne system designers could allow him to enter the information manually by keyboard; it could be entered from a machine-readable medium such as cards or tapes which have been prepared on another system; or it could be transferred into the static data area from another on-board database such as a navigation database. In view of the fact that this initialization activity is a preflight task which is performed prior to using the data link for other transactions, it can be completed in a relatively low workload environment where the pilot has more time to devote to the input process and to double-check the accuracy of the entered information.

The dynamic portion of the AMF, on the other hand, is the area in which data that are subject to change during the course of a flight are stored. Once a full-route clearance has been obtained for a proposed flight, virtually all subsequent transactions are revisions or modifications to information already received. This is true for all types of information exchanges including non-control, tactical, and strategic messages.

As illustrated in Figure 3-1, other parts of the airborne system may refer to information contained in the AMF. The autopilot may, for instance, use the current tactical assignments of heading, altitude, and speed if the pilot elects to have the autopilot operate directly from these parameters as contained in the AMF. With a more advanced FMS, he may use this feature to insert a complicated 3-dimensional flight path instruction from the ground and obviate the need for him to manually enter the data describing the flight path. In appropriately configured airplanes, he could also use this feature to do such things as automatically tune navigation or communication radios, or provide updated altimeter settings to a barometric altimeter system. This use of information in the AMF reduces the need for the pilot to act as a "modem" in the cockpit where he serves as an information transfer medium between inbound messages and their ultimate applications.

However, these potential applications of the information contained in the AMF place two stringent requirements on the CMS. First, the pilot must be cognizant of the data being entered into the various storage areas of the AMF. As will be described in a few examples below, this is accomplished by requiring the pilot to be in the loop of all transactions which could influence the contents of the AMF, and also by giving the pilot a "check-and-approve" authority for all inbound messages which are ultimately destined for the AMF. The check-and-approve process requires the pilot to first check an inbound message to determine its acceptability to him with regard to his current situation, and then to approve the entry of the message into the appropriate AMF space.

The second requirement on the CMS is that the information in the AMF must be accurate and up-to-date, reflecting the latest information and assignments from ATC, and the CMS should provide an appropriate notice to the pilot when the information could possibly be obsolete or inaccurate. This is particularly critical when the aircraft proceeds into an area where d/l coverage is marginal or non-existent, or where the link has failed. In these instances, the uncertainty of the accuracy of the information in the AMF increases as time progresses because no updates are being received by the CMS. This is also critical when consideration is given to the fact that both r/t and d/l can support the same transactions in many cases and there is the danger of the machine and the human being in separate information update loops.

3.2.2. Generic Procedures for D/L and R/T Message Exchanges

A better understanding of system and pilot responses and actions in the communications process can be gained by following through the steps needed to exchange messages between the aircraft and ground facilities. It is first assumed that the pilot has initialized the CMS by entering the appropriate data into the static portion of the AMF. These data include, as a minimum, the identifiers of the weather stations of interest to him for this flight, and the flight plan as filed with the ATC system. Therefore, at the outset of the flight the contents of the AMF may be as shown in Figure 3-4, which as an example illustrates what the pilot may have inserted prior to departing on the first leg of the hypothetical flight scenario presented in Appendix A. With these data in place, the pilot has a basis for starting data link discussions with appropriate ground facilities.

An underlying assumption in the development of these communications procedures is that r/t communications is always available either as the sole information exchange medium, or as a supplement to d/l information exchange. This gives rise to two modes of communication which must be considered, namely r/t-only and r/t + d/l. The procedures which are presented below are those which apply to the r/t + d/l mode of communications, while communications in the r/t-only mode can be performed using current procedures.

During the course of any given flight, it is possible that a d/l-equipped aircraft may transition into and out of areas of d/l coverage. Therefore it is necessary for the pilot and airborne system to be able to readily adjust to changes in communications modes, and also to be able to recognize when a planned or unplanned change of mode takes place. These changes of mode, and how the pilot and system respond to them, are not

AIRBORNE MESSAGE FILE

NON-CONTROL	STRATEGIC	TACTICAL	
			DYNAMIC DATA
WEATHER STATION IDENTIFIERS BOS, ORD, MKE, BUF, DTW, DSM, DEN,.......	**FILED FLIGHT PLAN** FLIGHT ID: TA297 TYPE: HDC-10/A TAS: 475 KNOTS DEP & TIME: BOS @ 2015 ALTITUDE: FL390 ROUTE: GDM. CAM. J547. BUF. CRL. SBN....ORD. ALTERNATES: MKE	NOT USED	**STATIC DATA**

FIGURE 3-4
INITIAL CONTENTS OF AIRBORNE MESSAGE FILE

treated in this section but are further addressed in Appendix B with examples and illustrations.

A final basic principal applied in the development of these procedures is that pilot and controller will establish the primary means (d/l or r/t) by which they will communicate, and will change the primary means of communication only when an equipment failure or limitation requires them to do so. In the r/t-only mode, the selection of the primary means of communication is fairly straightforward as r/t is the only means available. However, in the r/t + d/l mode, either means could be selected and in this case the pilot and controller must clearly agree on which of the two will be used as the primary means. This is required to prevent confusion between the pilot and controller over when and how messages will be transmitted, and also to prevent humans and machines from being placed in separate information update loops. It is assumed that if both d/l and r/t communications are available, then the pilot and controller will consider d/l to be the primary means of communication (with r/t as a supplement) and will apply these communication procedures until a change of mode is required by equipment failure or moving out of d/l coverage.

3.2.2.1 Non-Control Information Exchange Procedures

The simplest kind of transaction in which the pilot can engage is a request for non-control information from the ground system, such as a request for weather reports or airport information as contained in the Automatic Terminal Information Service (ATIS). As described in Section 2, the nature of non-control information is such that the pilot can tolerate modest delays in its receipt, and because it does not imply a change in the operating agreement between the pilot and controller, the only messages exchanged are a request and a reply. In addition, the entire message exchange process can be carried out on d/l without the need for r/t to supplement it.

To submit such a request, the pilot first constructs a request message for the desired piece of information. He would do this through the pilot interface to gain access to the static portion of the AMF. In a sense, he is using the interface as a "viewing port" on information contained in the AMF, and extracting those parts of the static data from which he can construct a request message. A description of a potential I/O device to allow him to do this is presented in the d/l scenario in Appendix B. It should be noted that the pilot is not restricted to requesting information about only those locations that have been entered into the static portion of the AMF. If the pilot became interested in non-control information about another location, he could use the interface to create a request message without relying on the data stored in the AMF. This would require more I/O effort on his part, such as making more keystrokes, but does allow him the flexibility to issue requests concerning locations which are not in the AMF static data area. The purpose of the static data is to simplify the message generation process for requests he is likely to make during the course of a given flight.

Once the pilot has selected the types of information he would like to obtain, he instructs the CMS to formulate an appropriate request message and transmit it to ground facilities via d/l. He might do this by depressing a "send" button on his interface which causes the message handler to gather the request from the interface, format it according to the appropriate link structure, and schedule the transmission of the request. Once the pilot instructs the CMS to issue the request for information, the CMS (primarily the message handler) automatically tends to the tasks necessary to bring this message exchange process to a suitable "closure." No further pilot involvement would be necessary until the CMS reaches this closure and informs the pilot of the end result of his request for information.

The interaction of the message handler and the ground system, once the request message has been transmitted, is depicted in Figure 3-5 in flow diagram form. The sequence of events which follow the request message is largely dependent on the operational status of the link and the type of response made by the ground system. In transmitting the request the message handler would perform appropriate record-keeping tasks to keep track of messages which have been issued. It would first ascertain that the ground system has received the request message by waiting for the ground system's acknowledgement, even though the acknowledgement does not yet contain the information desired by the pilot. Implicit in the ground system's acknowledgement of receipt is that a fixed time allowance should be made for the ground system to process the request and gather the information. If the ground system knows in advance that it will take a longer time to service the request, the additional time factor could be included as part of the acknowledgement. In a routine message exchange, the ground system would then gather the data requested by the pilot and transmit it back up to the airborne message handler in a reply message. The message handler, upon receiving and decoding the information, would then send back an acknowledgement to the ground system to indicate receipt, and

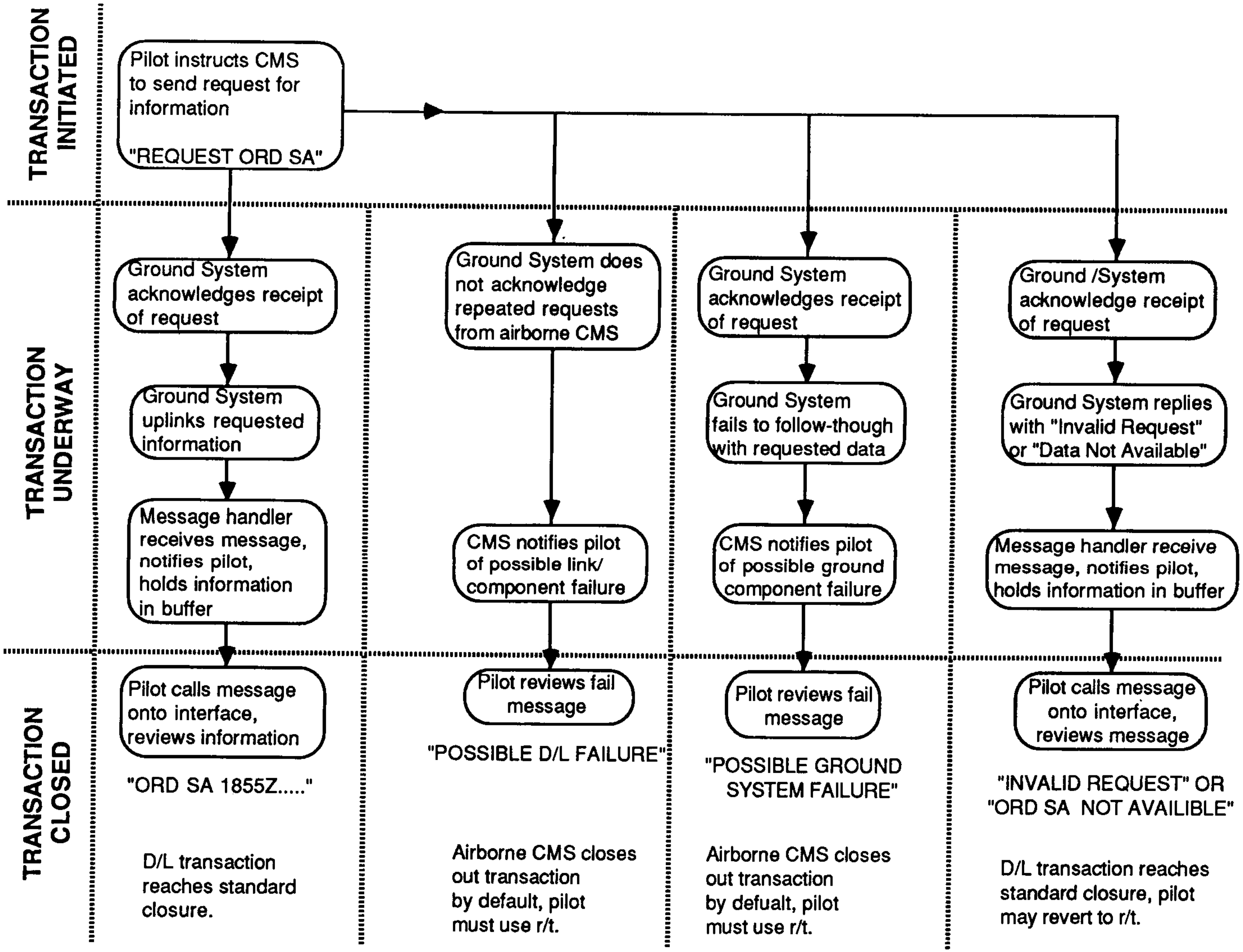

FIGURE 3-5
NON-CONTROL INFORMATION EXCHANGE FLOW DIAGRAM

forward the requested information to the buffer for pilot review. At this point the message exchange process has reached one of three possible states of closure for which no further action on the part of the airborne or ground system is necessary.

Variations to the routine message exchange process are also shown in Figure 3-5. If, after the request message is first transmitted, the ground system does not acknowledge receipt or for some reason the message handler does not properly decode the acknowledgement, the message handler would attempt to retransmit the request message as outlined in the second column of Figure 3-5. The retransmission of the request message could result in the proper acknowledgement from the ground (in which case the message exchange process would become routine again) or the acknowledgement may again be missed. In the second case the message handler may make additional attempts to transmit the request message before concluding that the link has failed. In the event of a failed link, the message handler would close out the transaction by default (i.e. without ever having a ground system acknowledgement), and forward an appropriate message to the buffer for pilot review.

Another type of failure condition may arise if the ground system does not provide, or the message handler cannot properly decode, the reply message containing the desired data once the acknowledgement has been received by the message handler. This condition may exist when the ground system's front-end data link processing components are able to acknowledge receipt of the request message, but for some reason the downstream components are unable to gather the requested data to provide a suitable response. After waiting an established time period, the message handler may try to reinitiate the process and transmit another request message. This action could return the process to a routine transaction if the ground subsequently acknowledges and provides the requested data, or it may result in another "indefinite" standby. In the latter case the message handler may conclude that some component of the ground system has failed and it issues the appropriate notice to the pilot through the buffer.

Even though each type of failure results in the same type of default closure and in the pilot being denied access to the information through d/l, the pilot may have an interest in knowing which type of failure occurred. The first type of failure (where no acknowledgement is received) indicates a basic d/l communications failure and could imply that other message types (such as strategic and tactical) cannot be exchanged on d/l as well. The second type of failure, however, means that a component other than the actual d/l is at fault. In this situation, the d/l system may still be capable of supporting other requests or other types of messages such as strategic or tactical exchanges.

The final variation to the routine response is illustrated in the far right column of Figure 3-5, in which the ground system replies that the request is not a valid one, or that the requested information is not available. An invalid request may come as a result of using an incorrect station identifier or requesting information which is not normally available for a valid station identifier (such as a request for a terminal forecast for a station which does not issue a terminal forecast). Also, in some instances data which are normally maintained in the weather database may not be available, in which case the ground system may provide the most recent available information, or otherwise indicate that the requested data are not available. In either case, the message handler is able to close out this transaction in a routine manner, and forwards the appropriate message to the buffer for the pilot.

The pilot and CMS actions in receiving non-control information are shown in Figure 3-6. After it is decoded by the message handler, (step 1) the information is retained in the buffer, and a notice is issued to the pilot that information is being held in the buffer for his review (step 2). The pilot calls the buffered information out onto his interface where he can review it (step 3). If he desires to "save" the information for later referral, he issues a command on the interface to enter the received information into the appropriate dynamic area of the AMF (step 4). Once entered into the AMF, the information is retained for later retrieval by the pilot, and other parts of the airborne system may refer to it. Examples of other systems using non-control information in the AMF include an FMS, which uses winds aloft reports for planning purposes, and an engine performance management system, which uses reported pressure, temperature, and field elevation to compute go-around thrust settings in preparation for landings. This information in the dynamic area of the AMF is maintained until it is superseded by more recent information requested by the pilot.

In the other mode of communication, where only r/t is available, the pilot and ground system must revert to current r/t procedures. However, the pilot has the option of manually inserting the information he receives over the voice radio into the AMF. The interface could be designed to allow the pilot to

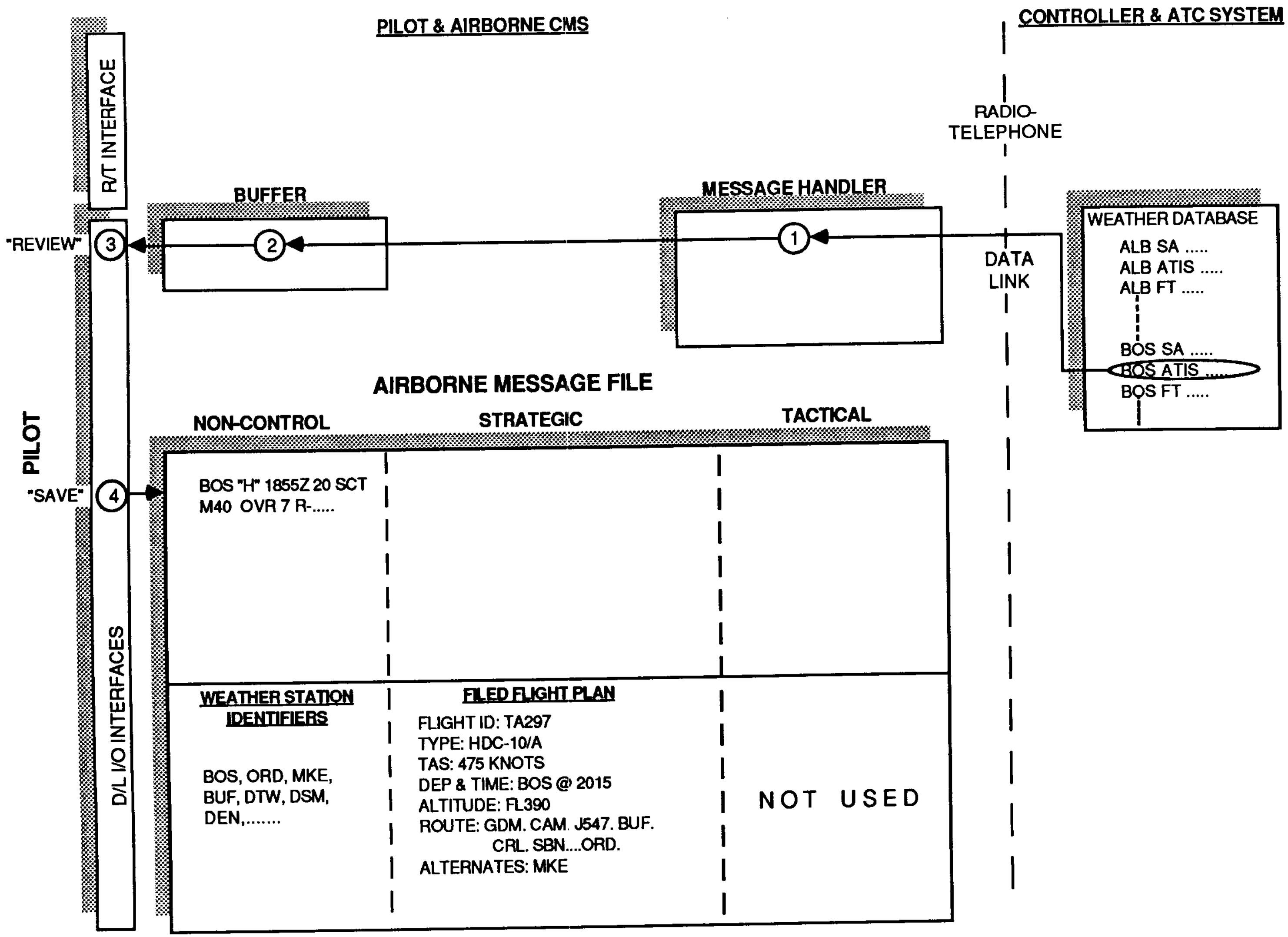

FIGURE 3-6
EXAMPLE OF PILOT/CMS ACTIONS WHEN RECEIVING NON-CONTROL INFORMATION MESSAGES

insert key information, such as altimeter settings, to enable other parts of the airborne system to still reference the AMF for the necessary non-control information. In the case of the barometric altimeter, for example, the pilot's setting of sea level pressure on the instrument serves as a potential interface through which pressure information could be entered into the appropriate part of the AMF dynamic storage area. If d/l communications become subsequently available, the altimeter system may revert to the process outlined above where the altimeter is updated automatically on the basis of messages that are uplinked to the airborne CMS and entered into the AMF by the pilot.

The foregoing discussion of non-control information exchanges has centered primarily on airborne requests for information which constitute a majority of the information exchanges in this category. However, there are instances where information is provided on an unsolicited basis, and where the ground system requests information from the airborne system (i.e. The request/reply roles are reversed). These can be accommodated with similar procedures which are briefly described here.

Examples of unsolicited information exchanges are blind issuances of significant weather advisories (such as Sigmets or Airmets). Accommodation of these on d/l requires the message handler to be prepared to decode these messages without notice, and to issue an acknowledgement back to the ground system after decoding the information. As for the request/reply type of exchange covered earlier, the information is then passed to the buffer and a notice is given to the pilot that a message is waiting for his review. If the ground system does not receive an acknowledgement of receipt from the airborne message handler, it would notify the controller that the pilot may not have received the information and prompt the controller to issue the information on r/t.

The last application of d/l to non-control information exchanges involves those in which the ground requests information from the air (such as position report, estimated times of arrival, and observed weather conditions and "ride" reports). These can be accommodated by reversing the roles and using procedures similar to those used for airborne requests for information, except that the pilot may need to be more directly involved in the generation of reply messages. However, the airborne system can facilitate the pilot's generation of reply messages by providing him a list of choices from which he can select appropriate responses.

3.2.2.2 Strategic Exchange Procedures

Because strategic messages are exchanged with the intent of reaching an overall agreement between the pilot and the ATC system, the procedures used to exchange them are somewhat more complicated than for non-control information exchanges. The process of reaching a strategic agreement involves more steps, such as submission of a proposed flight plan, receipt of an ATC clearance for IFR flight, and subsequent negotiation if the clearance is not acceptable to the pilot. In addition, the IFR clearance may be revised from time to time during the course of a flight which constitutes a change of the established strategic agreement. These additional steps in the process of reaching and maintaining a strategic agreement create more "branches" which require an appropriate return to closure. However, strategic exchanges are not excessively time-critical and can be somewhat tolerant of slight delays in their completion. In this section the procedures to establish a strategic agreement (such as submitting a flight plan and obtaining an initial IFR clearance) as well as those used to modify an existing clearance are described.

In today's ATC environment there are two different methods which can be used to reach an initial strategic agreement. The first and more common method is for the airspace user to submit to the ATC system, in advance of the actual flight, a proposed flight plan which indicates his overall objectives and the preferred means to achieve them. This is usually accomplished by a telephone contact, in-person visit, direct computer-to-computer link, or by prior arrangement such as the center-stored flight plan procedure. This advance filing practice is preferred because it gives the ATC system time to transcribe the proposed flight plan, analyze it with respect to active ATC-preferred routes and altitudes, and effect the necessary coordination between appropriate ATC facilities. The user then contacts the ATC system to obtain an IFR clearance which the system has generated on the basis of the filed flight plan.

The second method of reaching an initial strategic agreement is for the user to contact the ATC system directly and request an IFR clearance to conduct a certain operation without having filed a flight plan in advance. This is called a "pop-up" clearance request because it is usually requested by aircraft in flight with little or no advance notice given to the ATC system. In sending this request, the user may indicate his objectives and the preferred means to accomplish them in much the same format as for an advance-filed flight plan, or he may simply specify his destination and leave the determination of a route and altitude to the ATC system. Pop-up clearance requests are not a preferred method of initiating a strategic agreement because they tie up the r/t frequency for extended periods of time, and also because they create additional workload for the controller. However, as described below, the use of d/l to submit pop-up requests may eliminate these problems by facilitating automated flight plan processing.

Accommodating each of these methods of establishing an initial strategic agreement with d/l requires essentially the same procedures. In the case where the user has filed a flight plan in advance, he needs only to construct a message which uniquely identifies him to the ATC system and requests an IFR clearance on the basis of his submitted flight plan. Construction of this request message could be facilitated by the CMS as shown in Figure 3-7, which illustrates the flow of information from the static portion of the AMF to the pilot interface and on to the message handler. It should be noted that entry of the filed flight plan into the AMF is one of the pilot's preflight initialization activities which subsequently enables him to construct the request message, and also lets him review his originally filed flight plan during the flight. When the pilot instructs the CMS to issue this request for a clearance, the CMS automatically extracts that information from the AMF static data area which will uniquely identify the proposed flight to the ATC system. This would include, for instance, the aircraft's flight identifier (radio call sign), departure point and time, destination, and a notation that the proposed flight plan has been filed in advance.

Once the CMS message handler has issued a d/l clearance request message, the procedural interaction between the air and ground systems would be as shown in Figure 3-8. The first column illustrates the events that would take place if the ATC system responds with a clearance that is acceptable to the pilot. The ground system would first acknowledge that it has received the request message and indicate the appropriate r/t frequency to monitor should there be a need for r/t communications while this transaction is underway. Within a specified time period the ground system would issue a clearance back up to the airborne system. The message handler would acknowledge receipt of the up-linked clearance back to the ground, and would forward the clearance to the buffer and indicate to the pilot that a clearance message is waiting for his review. The pilot would then call up the contents of the buffer onto the pilot interface where he can review the clearance from the ground.

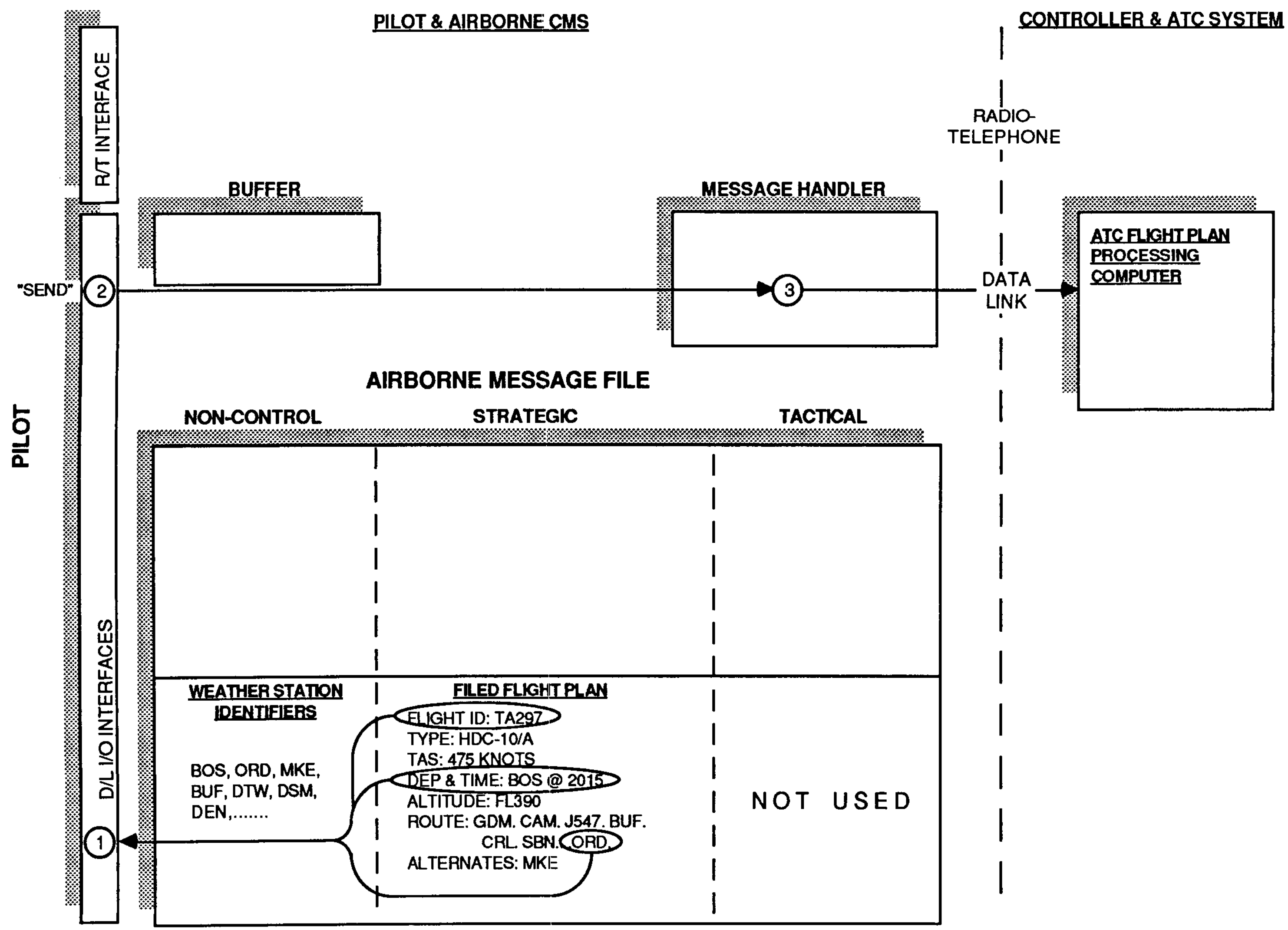

FIGURE 3-7
PILOT/CMS ACTIONS IN REQUESTING IFR CLEARANCE

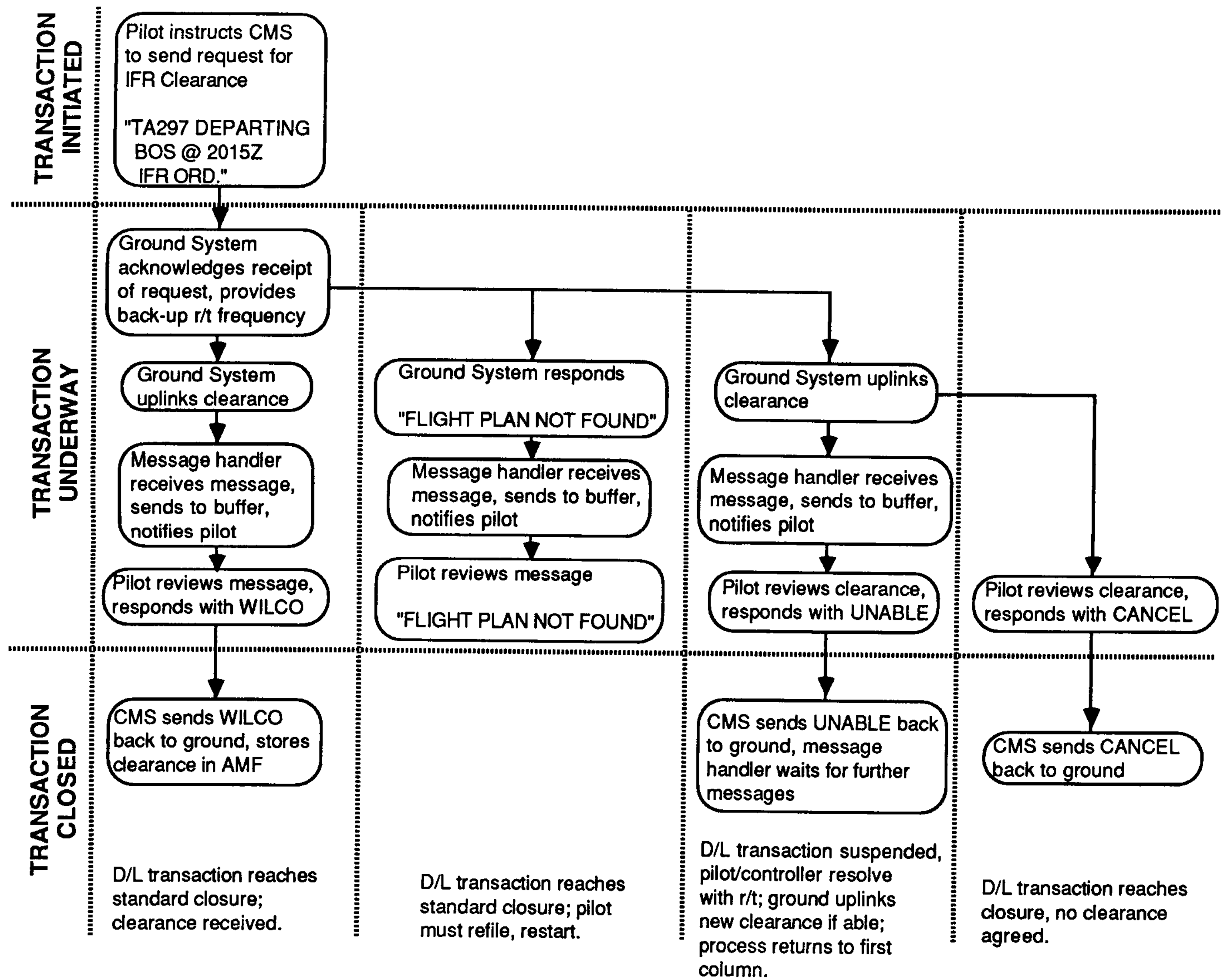

FIGURE 3-8
STRATEGIC EXCHANGE FLOW DIAGRAM

On the assumption that the clearance is acceptable to the pilot, he would instruct the CMS to issue a "Wilco" message back to the ground system. In addition to causing the CMS to issue a message back to the ground which "seals" the strategic agreement, the Wilco instruction also causes the CMS to enter the clearance into the dynamic portion of the AMF. This saves the active clearance for the pilot to review later if desired, and also saves it for the reference of other parts of the airborne system.

As for the exchange of non-control information messages, the message handler would manage the actual exchange process and would monitor it for the purpose of detecting possible d/l or ground system failures. For brevity, these branches of the flow diagram have not been reproduced in Figure 3-8, but would be comprised of same elements as in Figure 3-5. The CMS would close out these transactions which could not be satisfactorily completed by default, and would indicate the probable failure to the pilot.

The remaining two columns describe other possible closure states for this clearance request transaction. If, after it receives and acknowledges the request message, the ground system is unable to match the clearance request to a flight plan which has been filed in advance, the ground system may reply to the airborne system with a message indicating the flight plan could not be found. Because there is not enough information in the original clearance request message from the airborne system to infer what the flight intends to do, there is no way for the ground system to construct an improvised clearance: the pilot must either file another flight plan as described below. Receipt of a "flight plan not found" response from the ground closes out the transaction, and an appropriate notification is presented to the pilot.

The pilot's decision on the acceptability of the received clearance creates other branches in the flow diagram of Figure 3-8. In most instances the clearance as received from the ground is acceptable to the pilot, or at least tolerable to the point of being accepted by the pilot with the intent of negotiating modifications after the flight is underway. (The only point at which an IFR clearance becomes unmodifiable, practically speaking, is in the rare event of a communications failure.) However, provision should be made for the pilot to not accept a clearance and/or to cancel his request to participate as IFR traffic in the ATC system. Therefore, at the time the pilot reviews the clearance received from the ground, he is presented with choices of Wilco (described above), "Unable," and "Cancel." The Unable response allows the pilot to indicate that he will not be able to comply with the clearance as received on d/1, but still allows him to continue seeking a clearance which is more acceptable. When the pilot makes an Unable response, the CMS issues a message back to the ground indicating that the pilot has not accepted the clearance. Unlike the case for a Wilco response, the CMS takes no further action with the unaccepted clearance (such as storing it in the dynamic portion of the AMF), because no agreement has been reached between the pilot and controller. Once an Unable response has been received and acknowledged by the ground, d/1 transactions on this clearance request are suspended until the pilot and ATC system find an acceptable strategic agreement through r/t negotiation. R/t communications, in this case, would be conducted on the r/t frequency indicated with the ground system's first acknowledgement of receipt.

If the pilot and ATC system are able to find a suitable compromise clearance through r/t communications, the ground system would issue another clearance through d/1 for the pilot to review. This returns the process to the first column of Figure 3-8, in which the pilot responds with Wilco, and the CMS takes appropriate action to save the clearance in the AMF and issues a Wilco message back to the ground.

The pilot is also offered the opportunity to "Cancel" any d/1 request for a clearance at any time. If after his review of the clearance the pilot decides to drop his request to participate as IFR traffic in the ATC system, he may issue a Cancel response through the CMS which terminates the process. With this response the airborne and ground systems can close out this transaction without the uncertainty that would be associated with the pilot simply not responding at all to a non-desirable clearance.

The preceding discussion describes how the pilot may obtain a d/1 clearance on the basis of a flight plan which has been filed in advance. However, d/1 could also be used to file the flight plan itself and, when coupled with the procedures mentioned above, provide a means for the pilot to obtain an IFR clearance on a pop-up basis. The pilot would be required to generate a flight plan using the interface (or through the use of an on-board performance management system, if so equipped) to specify in enough detail what the flight intends to do, as well as other descriptive information such as r/t call sign, aircraft type, capabilities, etc. D/1 transmission of the proposed flight plan would reduce the controller workload associated with r/t pop-up clearance requests.

3.2.2.3 Tactical Message Exchange Procedures

The generic procedures to be used for the issuance of tactical instructions from the ground to the aircraft on d/l are shown in Figure 3-9. As noted in Section 2, tactical messages can be very time critical and, as a result, the receipt and acknowledgement of tactical instructions should be completed fairly quickly. Otherwise, the controller must promptly reissue the tactical message on the assumption that the aircraft did not receive the message in the earlier transmission. Therefore, in addition to providing for possible d/l failures while tactical exchanges are underway, the procedures outlined in Figure 3-9 specify actions in the case where the pilot or airborne CMS is tardy in completing a response.

The first column of Figure 3-9 illustrates the steps that would take place in a normal d/l exchange in which the ground system issues a tactical instruction and the pilot responds that he will comply. In this instance the ground-based system initiates the exchange process and performs appropriate record keeping to keep track of issued instructions. Once the airborne message handler receives and decodes the tactical instruction, it issues an acknowledgement of receipt back to the ground and also forwards the decoded message directly to the interface for pilot review and action. The potential time-criticality of tactical instructions makes them unsuitable for buffering and, hence, the message handler routes the message to the direct attention of the pilot for priority treatment. The means by which the interface would draw attention to the message is left to the discretion of I/O system designers; however, it is assumed that whatever means is employed would not be an awkward interruption to tasks the pilot might already be performing on the interface. If the pilot determines that he can comply with the tactical instruction, he makes a Wilco response through the interface which causes the CMS to perform two tasks. First, it issues a Wilco message back to the ground system, thereby completing the exchange process and establishing a new tactical agreement. Secondly, the CMS updates the appropriate area of the AMF with the details of the new tactical agreement.

The flow of information through the components of the airborne CMS, as well as pilot actions associated with this normal tactical message exchange on d/l are illustrated in Figure 3-10. The message handler first performs all of the assigned overhead functions associated with the receipt of this tactical message. After successfully decoding the message, the message

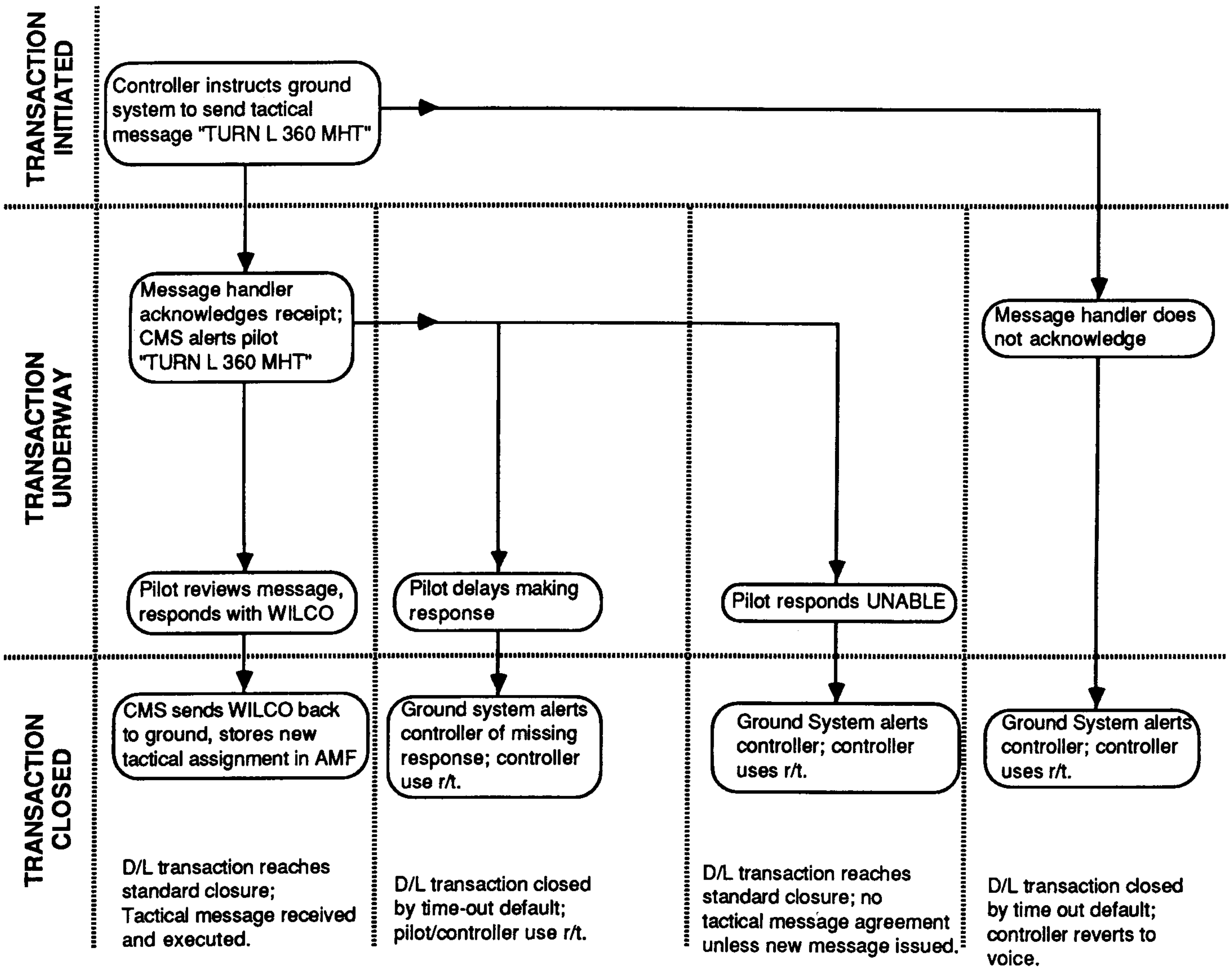

FIGURE 3-9
TACTICAL EXCHANGE FLOW DIAGRAM

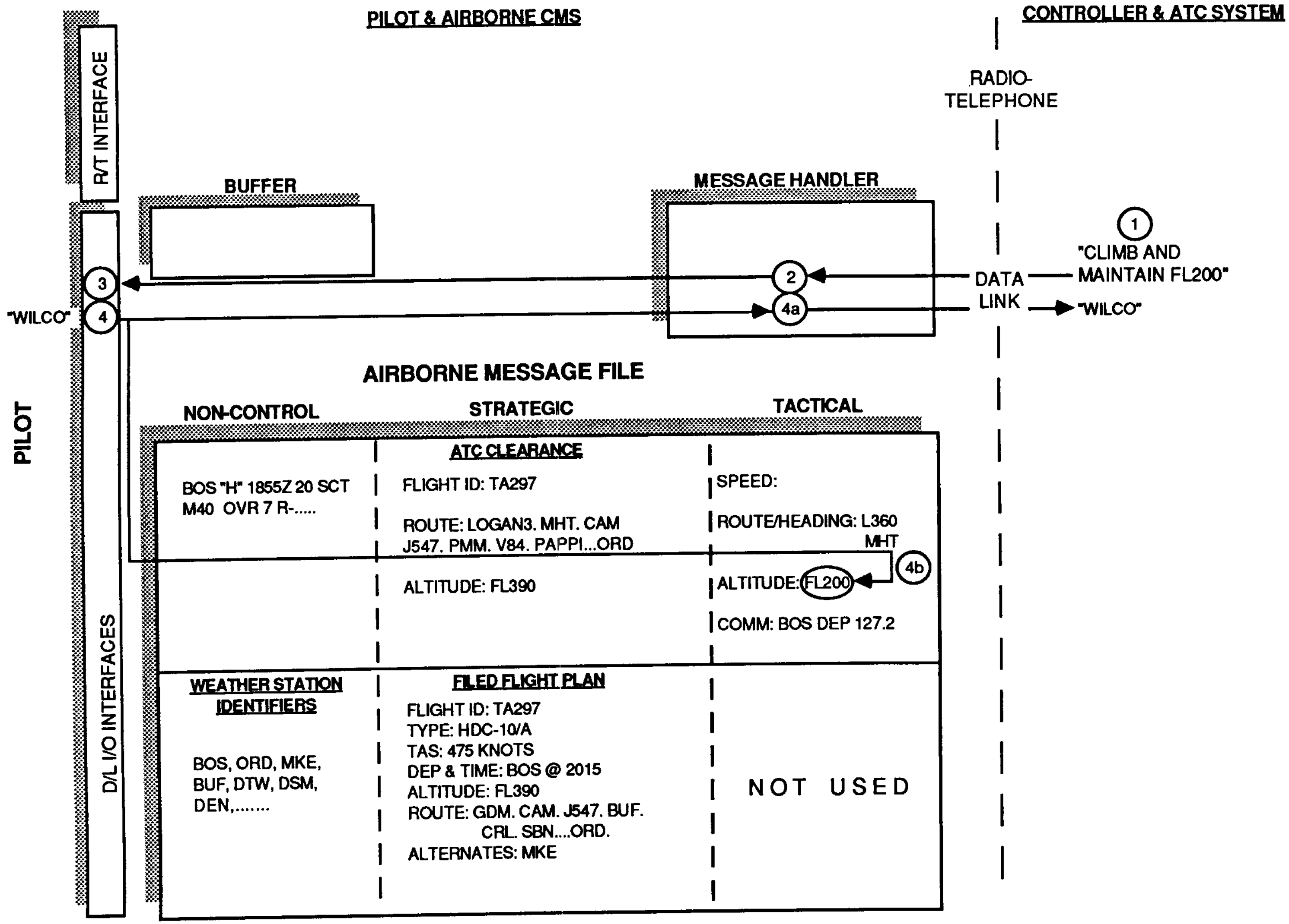

FIGURE 3-10
PILOT/CMS ACTIONS ON RECEIPT OF ACCEPTABLE TACTICAL INSTRUCTION

handler issues an acknowledgement to the ground which indicates only that the information was received, and it also forwards the message to the pilot interface for prompt disposition. The pilot is left with the functions of reviewing the message, checking its pertinence and desirability, and initiating an appropriate response. If the pilot agrees to comply with the instructions, he issues a Wilco response to the message on the pilot interface. This causes the CMS to issue a Wilco message back to the ground, and also for the appropriate entries in the AMF's dynamic data area to be updated. At this point, other parts of the airborne system may reference the contents of the AMF, because this information represents the latest data received on d/l, and information which has also been checked-and-approved by the pilot.

The desirability of allowing other parts of the airborne system to reference the updated and pilot-approved contents of the AMF becomes more apparent when one considers tactical (or strategic) instructions of an increasingly complex nature. Descent instructions, for example, which include speed, time, or altitude restrictions could be handled quite easily by the pilot through the check-and-approve process, and the likelihood of autopilot programming errors would be greatly reduced as the autopilot would be programmed from the contents of the AMF (rather than relying on the manual entry capabilities of the pilot).

Figure 3-9 also shows the recovery actions to be taken if, at any point in the transaction process, a delay is encountered in the delivery, acknowledgement, or Wilco response to an issued tactical instruction. Such delays could result from the airborne CMS's failure to issue an acknowledgement of receipt, from the pilot's lack of a timely response, or his indication that he cannot comply with the instruction through an "Unable" response. Because of the time criticality of these messages, the controller is promptly notified that the instruction may not have reached the pilot or that the pilot has indicated he cannot comply. In these instances the controller would revert to r/t communications and reissue the instructions if critical. When time permits, he may subsequently determine which situation prevails and re-establish or terminate the use of d/l as the primary mode of communication. If the controller elects to discontinue the use of d/l as the primary means of communication with a given aircraft, he would issue a final d/l instruction to the respective airborne CMS which would close out all outstanding transactions and also indicate that future transactions will be conducted on r/t. In this way, if the airborne CMS has not already assumed that the d/l has failed, it may take appropriate action to close out outstanding transactions and indicate to the pilot that r/t is now the primary means of data communication.

4. SUMMARY AND CONCLUSIONS

The concept presented in this paper should be considered as an initial step toward formalizing the role d/l could play in a future ATC communications system. It represents a departure from most of the past research efforts in this area which have tended to emphasize specific, isolated applications of d/l with less attention to some of the system-level issues raised and addressed here. Rather, the approach taken in this research effort was to first determine the requirements of a future communications system on the basis of both the shortcomings and the advantages of current r/t communications, and then take advantage of the unique characteristics of r/t and d/l to jointly satisfy those requirements. This systems approach, and the operational emphasis maintained throughout the effort, has resulted in a fairly comprehensive, high-level description of a future communications system which has several desirable characteristics.

First, it should be noted that in defining the role of d/l, it was necessary to make a logical allocation of tasks to the humans and the machines. This was accomplished by assigning to the human those tasks in which he needs or wants to be involved, and leaving to the machine those tasks it is capable of handling and which would represent perfunctory, workload-inducing effort for the human. Consideration was given in the assignment of tasks to the need to keep the human appropriately in-the-loop of information exchanges so that he can effectively manage the automated systems which may be using d/l information, and also to provide him an awareness of the operational status of his communications system. The procedures to use d/l which would result from this task allocation were also analyzed to ensure that they would be consistent from an operational standpoint.

Second, the concept recognizes the likelihood that both d/l and r/t will exist together, and makes provision for this in the system architecture and procedures. The coexistence of two modes of communicating raises two separate challenges for the communication system. First, because many message types can be exchanged over either medium, it is necessary for the system to abide by procedural "rules of exchange" so the human can build expectations on where information will be coming from. Secondly, the system has to clearly establish which of the possible modes of communication (such as r/t-only, or r/t+d/l) is in effect, and ensure that the human and machine can smoothly transition from one mode to another. These challenges were met in the system design by considering both d/l and r/t as companion elements in the communications process and by testing out the procedures which would be used to transition from one mode to another.

The concept also makes liberal provision for d/l to be integrated with other airborne systems, but does not make such integration a condition for successful use or implementation. The emphasis was primarily on the joint use of r/t and d/l as a communications tool, and secondarily on making provision for possible extended use of information obtained on d/l. This was accomplished by adhering to the principle of keeping information in the AMF as up-to-date as possible through appropriate procedures and system responses, and by allowing other elements of the airborne system to refer to information in the AMF. There is no requirement, however, for the information to venture beyond the AMF for the concept to be valid as an approach to communications. As a result, the concept can be applied with equal ease to sophisticated cockpits having complicated 4D flight management systems, for example, or to simpler airborne systems having relatively few or no advanced features.

A final desirable feature is that the concept can be introduced gradually and can accommodate advanced ATC applications. The partitioning of message types into major categories and subcategories, with procedures established to govern their exchange on d/l, makes it possible to implement parts of this concept without affecting the potential for other parts to be implemented. If, for instance, the peripheral mechanisms to support d/l exchange of weather data were in place before those needed to support tactical or strategic messages, the concept could be partially implemented without jeopardizing the potential for future applications involving strategic or tactical messages. This feature of growth and adaptability results from first describing the end-state, and then prescribing the steps that might be taken to reach it.

4.1 Recommendations for Future Research

There are several areas where additional research is needed to provide progress in the use of d/l as part of an ATC communications system. First, the work presented in this report is an initial strawman concept and should be reviewed and refined by experts in various disciplines. While it was intended that the concept be the result of a comprehensive research effort, only a broader review and critical assessment will ensure a truly comprehensive product.

Additionally, some of the basic premises of the concept should be validated in dedicated simulations and experiments. Low or moderate fidelity simulations would suffice to study some of the general phenomena associated with d/l transactions, but these should be followed by higher fidelity simulations in an attempt to reveal potential problem areas. Because the human is an integral part of the proposed system concept, experiments with human subjects should key on the occurrence of errors, blunders, and other miscues, as well as on the potential for improving his work environment and effectiveness through d/l implementation.

As a matter of course, the conduct of these experiments and simulations will require the concurrent development of appropriate I/O interfaces and also the mechanisms used to conduct d/l transactions themselves, such as the lower layers of the OSI reference model. However, with a refined end-state vision of the role d/l will play in the future ATC communications system, resolution of the remaining technical issues should be well within grasp.

APPENDIX A

BASIC RADIOTELEPHONE COMMUNICATIONS SCENARIO

In this appendix a scenario describing radiotelephone communications procedures is presented. It is predicated on an actual flight performed by a scheduled air carrier DC-10 from Boston (BOS) to Chicago-O'Hare (ORD) to Denver (DEN). Information exchanges between the aircraft and ATC facilities are presented in a narrative, time-sequenced script format, and procedures necessary to support ATC-related communications are discussed. This scenario was intended to serve as a baseline from which alternative data link procedures and concepts could be evaluated when assumptions are made about airborne and ATC functional capabilities, and when variations to normal operating conditions are introduced.

A.1 Background Information on the BOS-ORD Segment

It will be assumed that the hypothetical flight, which will be called Transair Flight 297 (TA297), is conducted on a daily basis using DC-10 aircraft. The flight is scheduled to depart BOS at 1610 EDT and arrive at ORD at 1738 CDT, which results in a scheduled block-to-block time of 2:28. On the second leg of the flight, scheduled departure from ORD is 1844 CDT and arrival at DEN is 2014 MDT, which yields a block-to-block time of 2:30. It is assumed that flight planning is performed through a central company dispatch facility which maintains direct communications with the computerized databases of the National Weather Service, FAA ARTCC computers, plus company maintenance and scheduling computers. For a flight between a given city pair, airlines often have one or more preconstructed routes planned in advanced, including ATC-preferred routes if any are designated. Based on latest winds and weather, the minimum-cost route and altitude is usually selected and submitted in the filed flight plan. On occasion, a route other than the minimum-cost is selected to avoid severe weather or traffic congestion.

When the flight plan is filed the FAA computers first check the submission for completeness and compatibility with the ATC system. If an ATC-preferred route is active between the city pair, the computer automatically amends the route accordingly and forwards both the filed route and amended route to the appropriate control positions in the affected ATC facilities. For the purposes of illustration, it is assumed that the filed route for both the BOS-ORD and ORD-DEN legs for TA297 is something other than the active ATC-preferred route, and when the IFR clearances are obtained the flight will be cleared according to the active ATC-preferred routes. This will require the crew to review the clearances in more detail as it is not according to the filed flight plans with which the crew are familiar, and it also permits illustration of the common practice of seeking modifications to the original IFR clearance after the flight has departed.

The flight plan filed in advance for TA297 for the BOS-ORD segment is as follows:

Identification: TA297
Aircraft Type and Equipment: H/DC10/A
True Airspeed: 475 Knots
Departing: BOS
Proposed Departure Time: 2015 UCT (1615 EDT)
Requested Cruising Altitude: FL390
Route of Flight:

GDM.CAM.J547.BUF.CRL.SBN.....ORD

(Read as Boston direct to Gardner VOR, direct to Cambridge VOR, J547 to Buffalo VOR, direct to Carleton VOR, direct to South Bend VOR, then direct to O'Hare).

Estimated Time En Route: 2:20
Alternate Airports: MKE (Milwaukee)

<u>Discussion</u>: TA297 is scheduled to leave the gate at BOS at 2010Z. Approximately 1:30 prior to departure, the TA dispatch facility prepares a flight plan forecast, a weather briefing, and a dispatch release message. The flight plan forecast contains pertinent information such as the flight plan as filed with ATC, a flight log showing fuel burns and estimated times en route, and comparative cost summaries for the flight at the filed altitude and nearby altitudes. A layout of the planned route is given in Figure A-1 which also shows the ATC facilities which will be handling this flight. After completing other preflight planning and aircraft preparation duties, the cockpit crew enters the aircraft and gets ready for flight where the time-based script begins.

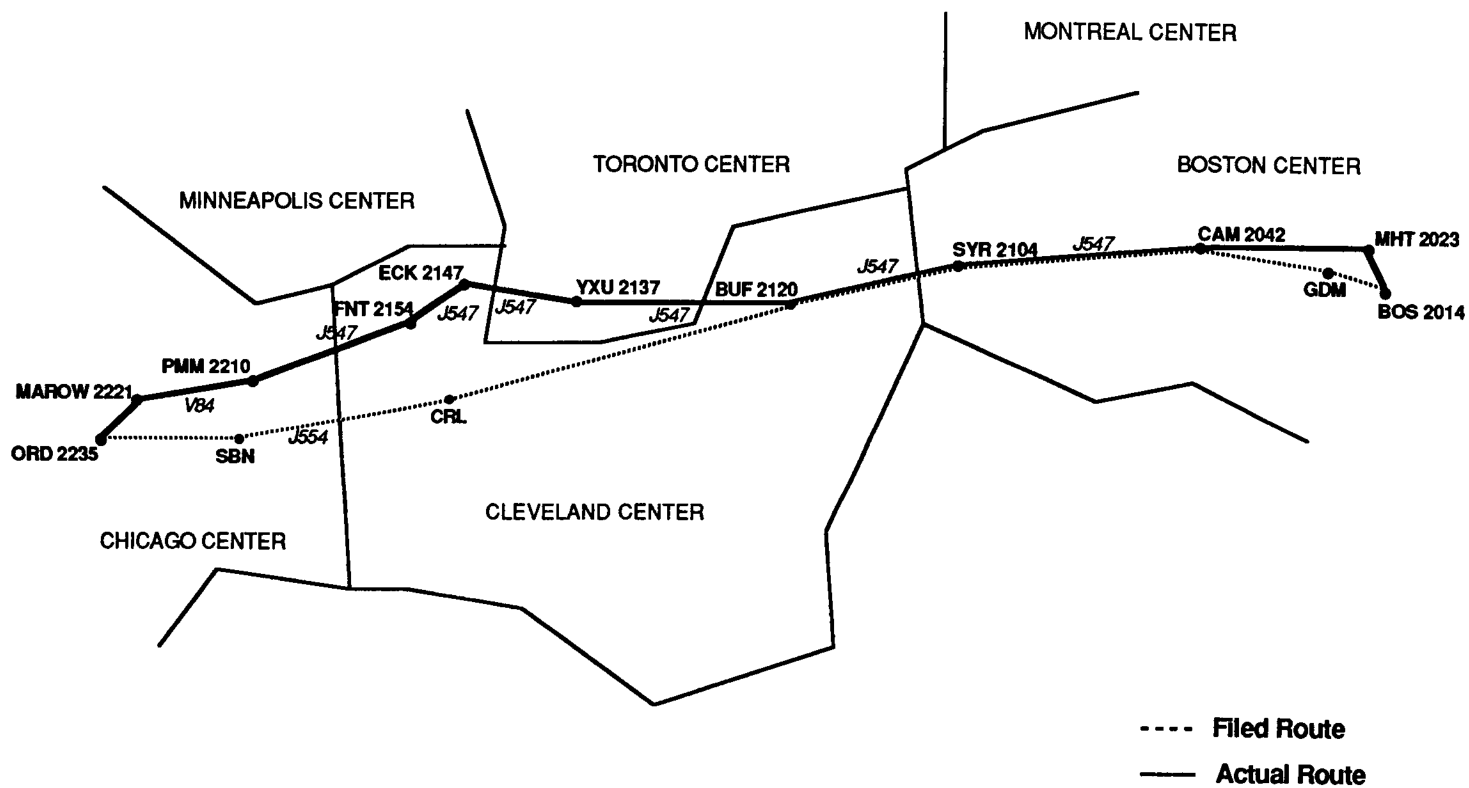

FIGURE A-1
FILED AND ACTUAL ROUTE FOR TA297 BOS - ORD

General Description of Tables A-1 through A-62

The following tables describe the ATC-related voice communications for the hypothetical flight. Each table contains four columns describing the following: (1) the time of the transaction or event, (2) whether the message was issued from air-to-ground (AG) or from ground-to-air (GA), (3) the actual voice r/t message, and (4) a commentary on procedures involved in the exchange and how the information is being used.

TABLE A-1
ACQUISITON OF DEPARTURE ATIS

TIME (GMT)	AG* GA	INFORMATION CONTENT	REMARKS AND USAGE
1950	GA	(Automatic Terminal Information Service (ATIS) - repetitively broadcast in coverage on 125.5 MHz.) "BOSTON LOGAN AIRPORT INFORMATION HOTEL: 1855 GREENWICH WEATHER, 2000 SCATTERED, MEASURED CEILING 4000 OVERCAST, VISIBILITY 7 IN LIGHT RAIN TEMPERATURE 75, DEWPOINT 68, WIND 360 DEGREES AT 10 KNOTS, ALTIMETER 29.98, ILS APPROACHES TO RUNWAY 4-RIGHT, 33-LEFT, LANDING 4-RIGHT, 4-LEFT, 33-LEFT, DEPARTING 4-RIGHT ADVISE ON INITIAL CONTACT YOU HAVE 'HOTEL'."	• Used by aircrew for: (a) Takeoff performance planning, (b) Departure route preparation, and (c) Future comm instructions. • Crew usually makes written copy of ATIS information for later reference

*AG = Air-to-Ground, GA = Ground-to-Air

TABLE A-2
REQUESTING/RECEIVING IFR CLEARANCE

TIME (GMT)	AG/ GA*	INFORMATION CONTENT	REMARKS AND USAGE
		Request for Clearance	
2005	AG	"BOSTON CLEARANCE, TRANSAIR 297 HEAVY, GATE 5 WITH ATIS HOTEL, READY FOR CLEARANCE TO CHICAGO."	• Indicates crew prepared to copy down clearance, and has latest airport conditions.
	GA	"TRANSAIR 297 HEAVY, BOSTON CLEARANCE, YOU ARE CLEARED TO CHICAGO-O'HARE VIA LOGAN3 DEPARTURE TO MANCHESTER DIRECT CAMBRIDGE J547 PULLMAN V84 MARROW DIRECT MAINTAIN FLIGHT LEVEL 390, DEPARTURE FREQUENCY 127.2, SQUAWK 4614."	• Indicates aircraft id (including transponder code), clearance limit, route, altitude, and future communications.
	AG	"CLEARANCE TRANSAIR 297 HEAVY WILL HAVE TO CHECK THAT ROUTING, STANDBY."	• Because this is not the route that TA297 filed and is prepared to fly, the crew must review it to determine if it is still acceptable. It will be assumed to be acceptable, although the crew may seek modifications once airborne.
	AG	"TRANSAIR 297 HEAVY CLEARED TO CHICAGO VIA LOGAN3 DEPARTURE TO MANCHESTER DIRECT CAMBRIDGE J547 PULLMAN V84 MARROW DIRECT MAINTAIN FLIGHT LEVEL 390, 127.2, 4614."	• Readback by crew ensures clearance copied and understood correctly, signifies acceptance of clearance if not stated otherwise.
	GA	"TRANSAIR 297 HEAVY, READBACK IS CORRECT, EXPECT NO TAKEOFF DELAYS, CONTACT GROUND 121.9 WHEN READY TO PUSH BACK."	• States readback is correct (if so), states delay and future communication instructions.
	AG	"TRANSAIR 297 HEAVY (ROGER)"	• Indicates TA297 got last message. Signs off this frequency.

*AG = Air to Ground, GA = Ground to Air

TABLE A-3
TAXI INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2010	AG	"BOSTON GROUND, TRANSAIR 297 HEAVY, GATE 5, READY FOR PUSHBACK."	• States aircraft ident, location, and request.
	GA	"TRANSAIR 297 HEAVY BOSTON GROUND, CLEARED TO PUSH-BACK FROM GATE 5, CALL WHEN READY FOR TAXI."	• Grants request, specifies limit of approval and future communication coordination.
	AG	"TRANSAIR 297 HEAVY, ROGER."	• Aircraft acknowledges receipt and understanding of instructions.
2012	AG	"GROUND, TRANSAIR 297 HEAVY, READY TO TAXI."	• Aircraft id, and request.
	GA	"TRANSAIR 297 HEAVY, TAXI TO 4R VIA SIERRA, HOLD SHORT OF 4L."	• Indicates ultimate goal of instructions and limitations.
	AG	"TRANSAIR 297 HEAVY, ROGER."	• Message received and will comply.
	GA	"TRANSAIR 297 HEAVY, CROSS 4L AND 9 ON SIERRA."	• Limit removed.
	AG	"TRANSAIR 297 HEAVY, ROGER."	• Message received and understood.

TABLE A-4
OBTAINING COMPANY TAKEOFF PLANNING DATA

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2011		(While monitoring ground control during taxi, TA297 contacts the Transair Ramp Office at Boston for the final weight and balance figures, and to report out and expected off times. Some airlines perform this on ACARS.)	
	AG	"TRANSAIR RAMP, TRANSAIR 297 HEAVY, READY TO COPY THE NUMBERS."	• TA297 indicates that Transair ramp can proceed to give the necessary data on its next transmission.
	GA	"TRANSAIR 297 HEAVY, TRANSAIR RAMP, YOU HAVE 39 IN FIRST, 160 IN COACH, TAKEOFF FUEL 60,000, TAKEOFF WEIGHT 540,044, CG 22.7."	• Crew will use these data for computing trim settings and takeoff speeds; therefore crew makes written record.
	AG	"OK, TRANSAIR 297 HEAVY HAS 39; 160; 60,000 POUNDS: 540,044 POUNDS: AND 22.7 CG. OUT AT 2010, ESTIMATED OFF AT 2020."	• Crew reads back the "numbers" and provides out and off times to company to update system schedules and times.

TABLE A-5
TAKEOFF CLEARANCE AND HANDOFF TO DEPARTURE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2014	AG	"BOSTON TOWER, TRANSAIR 297 HEAVY, READY FOR TAKEOFF."	• States identity and request.
	GA	"TRANSAIR 297 HEAVY, HOLD SHORT, LANDING TRAFFIC."	• States restriction and reason.
	AG	"TRANSAIR 297 HEAVY, ROGER."	• Hold restriction received and will comply.
	GA	"TRANSAIR 297 HEAVY, POSITION AND HOLD ON 4R."	• As landing traffic passes threshold, tower issues position and hold instructions.
	AG	"TRANSAIR 297 HEAVY, ROGER, POSITION AND HOLD."	
	GA	"TRANSAIR 297 HEAVY, CLEARED FOR TAKEOFF."	• When traffic exits runway, tower clears TA297 for takeoff.
	AG	"TRANSAIR 297 HEAVY, ROGER, CLEARED FOR TAKEOFF."	• TA297 acknowledges.
2015	GA	"TRANSAIR 297 HEAVY, CONTACT DEPARTURE."	• Tower controller instructs TA297 to contact departure control facility. The frequency was preassigned as part of the IFR clearance.
	AG	"TRANSAIR 297 HEAVY, ROGER." (TA297 tunes in 127.2 to contact next facility.)	

TABLE A-6
INITIAL CHECK-IN ON NEW FREQUENCY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2015	AG	"BOSTON DEPARTURE, TRANSAIR 297 HEAVY, THROUGH 1500 FEET."	• Identification, altitude given to new facility on initial call. Controller cross-checks verbally reported altitude with aircraft's Mode C returns.
	GA	"TRANSAIR 297 HEAVY, BOSTON DEPARTURE, RADAR CONTACT."	• Indicates radio communication and radar contact established--crew need not issue position reports which would be required at compulsory fixes if radar contact not established.

TABLE A-7
DEPARTURE TACTICAL INSTRUCTIONS
AND TRANSITION TO EN ROUTE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
		Note: Procedurally, Transair 297 follows the Logan-3 departure in the absence of any other instructions from ATC (See Figure A-2).	
2017	GA	"TRANSAIR 297 HEAVY, TURN LEFT HEADING 360, PROCEED DIRECT MANCHESTER."	• States instructions sequentially: a left turn then direct to the navigation aid.
	AG	"LEFT TO 360, DIRECT MANCHESTER, TRANSAIR 297 HEAVY (ROGER)."	• Instructions received and will comply.
2019	GA	"TRANSAIR 297 HEAVY, CLIMB AND MAINTAIN FL200."	• According to SID, TA297 would have to level off at 5000 ft until receiving a clearance to climb higher.
	AG	"TRANSAIR 297 HEAVY, LEAVING 5000 FOR FL200."	
	GA	"TRANSAIR 297 HEAVY, CONTACT BOSTON CENTER 134.75."	• Handoff to next facility.
	AG	"TRANSAIR 297 HEAVY TO 134.75, ROGER."	• Message received and will comply.

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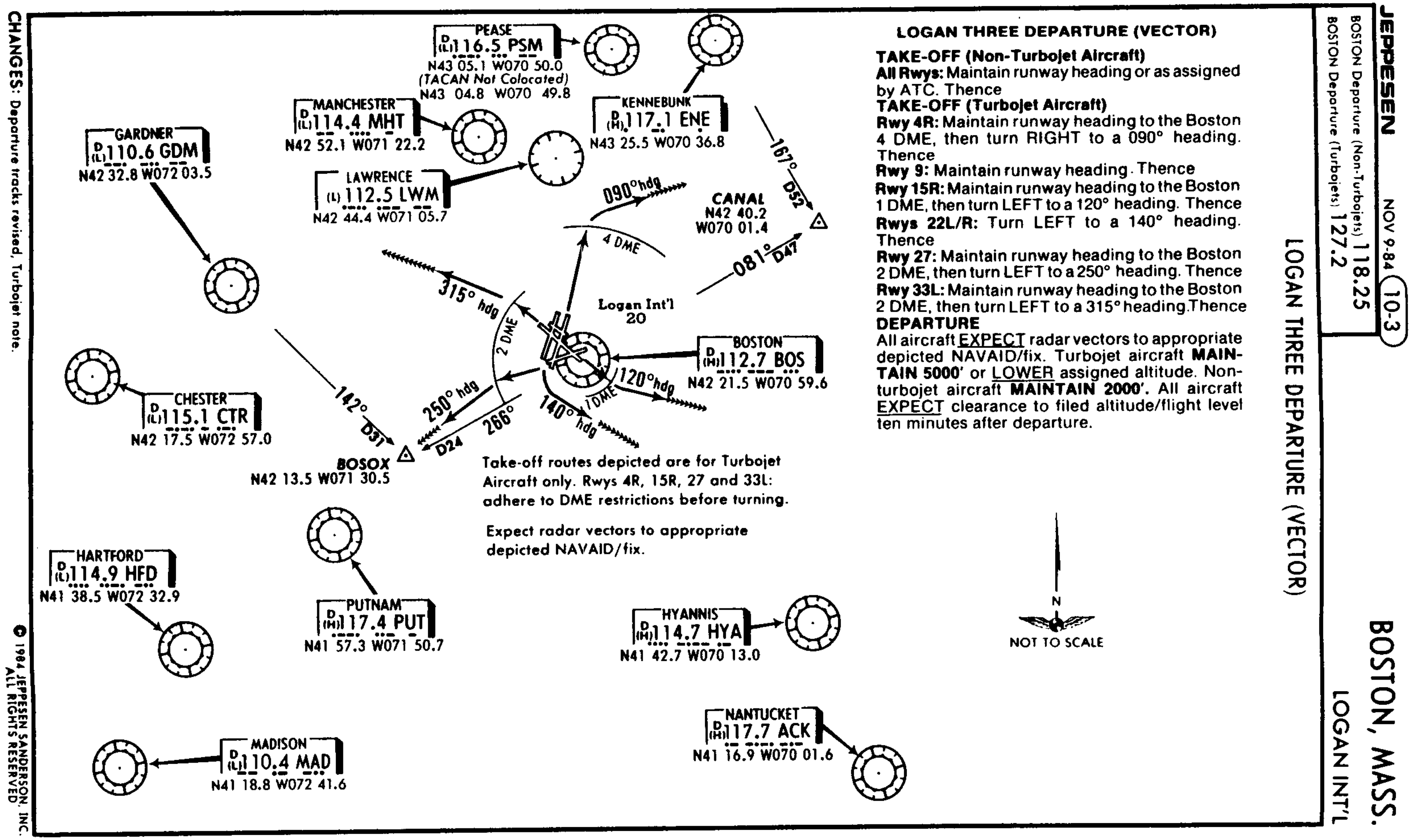

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FIGURE A-2
LOGAN-THREE STANDARD INSTRUMENT DEPARTURE

TABLE A-8
NEW FREQUENCY CHECK-IN AND TRAFFIC ADVISORY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2020	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY, 8000 FEET CLIMBING TO FL200."	• States identity and altitude on initial callup; also reports the flight's target altitude for this climb (FL200) although it is not required to do so.
	GA	"TRANSAIR 297 HEAVY, BOSTON CENTER, RADAR CONTACT."	• Indicates radio and radar contact established; position reporting not required.
	GA	"TRANSAIR 297 HEAVY, TRAFFIC ONE O'CLOCK, 4 MILES, SOUTHWESTBOUND, 8500 FEET UNVERIFIED."	• Center issues standard traffic advisory for non-controlled, Mode C equipped target.
	AG	"TRANSAIR 297 HEAVY, LOOKING, NO CONTACT."	• Traffic info received, not spotted visually.
	GA	"TRANSAIR 297 HEAVY, TRAFFIC NO LONGER A FACTOR."	• Controller may continue with traffic advisories until crew sees it, or it is no longer a factor.
	AG	"TRANSAIR 297 HEAVY, ROGER."	

TABLE A-9
PILOT REQUEST TO REVISE IFR CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2021	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY REQUESTING DIRECT TO CAMBRIDGE VOR."	• To cut the corner a bit, TA297 requests skipping Manchester VOR to proceed direct to Cambridge VOR.
	GA	"TRANSAIR 297 HEAVY, PROCEED DIRECT TO CAMBRIDGE VOR, THEN FLIGHT PLAN ROUTE."	• Controller reclears TA297 as requested. This constitues a revised strategic agreement (IFR clearance) to Cambridge with the original clearance to be resumed at Cambridge.
	AG	"TRANSAIR 297 HEAVY, ROGER, DIRECT, CAMBRIDGE FLIGHT PLAN ROUTE."	
2028	GA	"TRANSAIR 297 HEAVY, CLIMB AND MAINTAIN FL390."	• Levelling restriction at FL200 removed, flight cleared up to cruise altitude.
	AG	"TRANSAIR 297 HEAVY, ROGER, CLIMBING TO FL390."	

TABLE A-10
TRANSMISSION OF OPERATIONS DATA TO COMPANY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2030		(At this time TA297 crosses 18,000 feet, so all altitude references will be made with respect to the 29.92 in. Hg datum, and called Flight Levels (FL). At any time above 10,000 ft. MSL and while monitoring the assigned ATC frequency, TA297 contacts a Transair company facility to issue out and off times. This alternately may be performed through Arinc Radio, or through ACARS. The voice format of the "Off" report is shown here to illustrate the information exchange.)	
	AG	"TRANSAIR RADIO (OR ARINC RADIO), TRANSAIR 297 HEAVY, OFF REPORT."	• On initial call-up, crew informs Transair Radio to prepare to copy an "Off" report on the next transmision. Standard formats exist for a number of air-to-ground reports such as delay reports, enroute weather reports, and maintenance reports.
	GA	"TRANSAIR 297 HEAVY, THIS IS TRANSAIR RADIO, GO AHEAD."	• Indicates Transair Radio is ready to copy.
	AG	"TRANSAIR 297 HEAVY, PLANE 808TA, DEPARTED BOSTON, OUT 2010, OFF 2015, FUEL 60500, ESTIMATE O'HARE AT 2220, OVER."	
	GA	"TRANSAIR 297 HEAVY, ROGER, I HAVE YOUR REPORT."	• Readback not generally required for non-critical information, unless reception quality is poor.

TABLE A-11
STANDARD COMMUNICATIONS HANDOFF INVOLVING
ERRONEOUSLY COPIED FREQUENCY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2037	GA	"TRANSAIR 297 HEAVY, CONTACT BOSTON CENTER NOW ON 135.25, GOODDAY."	
	AG	"135.35, TRANSAIR 297 HEAVY, GOODDAY." (TA297 tunes in an erroneous frequency of 135.35 and attempts to contact next sector.)	
	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY, THROUGH FL290 FOR FL390." (Assume no response from Boston Center on this frequency.)	
	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY, THROUGH FL298 FOR FL390." (Still no reply.)	• TA297 repeats the standard check-in message, assuming that controller might have been preoccupied on first transmission.
	AG	BOSTON CENTER, TRANSAIR 297 HEAVY, HOW DO YOU READ?" (Still no reply.)	• Crew suspects a communications problem and queries the controller if he reads TA297 at all.

TABLE A-11
(Concluded)

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2039		(TA297 cannot contact the next sector on the assigned frequency. The crew would note if other conversations could be overheard on the radio, which would indicate that TA297 is having trouble transmitting. If no other conversations are heard, the crew may suspect that it was not assigned the correct frequency, or had copied the incorrect one. Having saved the previous frequency, TA297 re-contacts the previous controller.)	
	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY."	
	GA	"TRANSAIR 297 HEAVY, THIS IS BOSTON CENTER, GO AHEAD."	
	AG	"ROGER, SIR, THERE'S NOBODY HOME ON 135.35."	• TA297 says unable to contact center on 135.35.
	GA	"THATS'S NOT THE RIGHT FREQUENCY; TRY 135.25."	• Controller identifies problem and tells TA297 to try again.
	AG	"OK, THAT WAS THE PROBLEM: TRANSAIR 297 HEAVY TO 135.25, GOODDAY."	

TABLE A-12
STANDARD COMMUNICATIONS CHECK-IN

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2041	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY WITH YOU FL320 FOR FL390."	• Standard check-in.
	GA	"TRANSAIR 297 HEAVY, BOSTON CENTER, GOOD AFTERNOON."	
2042		(TA297 crosses Cambridge VOR (CAM) at FL330.)	
2050		(TA297 reaches FL390 about 40 miles west of CAM, and establishes normal cruise configuration.)	
2055	GA	"TRANSAIR 297 HEAVY, CONTACT BOSTON CENTER ON 127.9, GOODDAY."	
	AG	"TO 127.9, TRANSAIR 297 HEAVY, ROGER."	
		(TA297 tunes in 127.9 to contact next sector.)	
	AG	"BOSTON CENTER, TRANSAIR 297 HEAVY WITH YOU, LEVEL FL390."	
	GA	"TRANSAIR 297 HEAVY, ROGER, LEVEL 390."	

TABLE A-13
STANDARD COMMUNICATIONS HANDOFF

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2108	GA	"TRANSAIR 297 HEAVY, CONTACT CLEVELAND CENTER ON 134.75."	
	AG	"GOING OVER TO CLEVELAND CENTER NOW ON 134.75, TRANSAIR 297 HEAVY."	
2109	AG	"HELLO CLEVELAND CENTER, TRANSAIR 297 HEAVY, LEVEL FL390."	
	GA	"TRANSAIR 297 HEAVY, CLEVELAND CENTER GOOD AFTER-NOON."	

TABLE A-14
ACQUISITION OF WEATHER INFORMATION

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2113		(TA 297 maintains listening watch on Cleveland but contacts Buffalo Flight Watch for weather data.)	
	AG	"BUFFALO FLIGHT WATCH, TRANSAIR 297 HEAVY OVER ROCHESTER FL390."	• Ident, altitude, and position on callup.
	GA	"TRANSAIR 297 HEAVY, BUFFALO FLIGHT WATCH, GO AHEAD."	• Radio communication established, ready for request.
	AG	"ROGER BUFFALO, TRANSAIR 297 HEAVY REQUEST LATEST CHICAGO WEATHER."	• Weather data for planning landing/ go-around performance and arrival at ORD.
	GA	"TRANSAIR 297 HEAVY, CHICAGO O'HARE WEATHER AT 2055 GREENWICH, MEASURED 900 OVERCAST 2 MILES RAINSHOWERS AND FOG, TEMPERATURE 71 DEW POINT 70, WIND 260 AT 8, ALTIMETER 29.85."	
	AG	"TRANSAIR 297 HEAVY COPIES ALL THAT, THANK YOU."	• Concludes communications with Flight Watch
2120		(TA297 crosses Buffalo VOR (BUF) at FL390.)	

TABLE A-15
DENIED REQUEST FOR MODIFIED CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2125	AG	"CLEVELAND CENTER, TRANSAIR 297 HEAVY REQUESTS BUFFALO DIRECT CARLETON DIRECT SOUTH BEND DIRECT O'HARE."	• Crew attempts to return the IFR clearance back to the route TA297 originally filed.
	GA	"TRANSAIR 297 HEAVY, UNABLE ON THAT REQUEST ON ACCOUNT OF TRAFFIC SATURATION NEAR SOUTH BEND."	

TABLE A-16
STANDARD COMMUNICATIONS HANDOFF

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2128	GA	"TRANSAIR 297 HEAVY, CONTACT TORONTO CENTER ON 131.3."	
	AG	"TORONTO CENTER ON 131.3, TRANSAIR 297 HEAVY SO LONG."	
	AG	"TORONTO CENTER, TRANSAIR 297 HEAVY, AT FL390."	
	GA	"TRANSAIR 297 HEAVY, TORONTO CENTER, GOOD AFTERNOON."	

TABLE A-17
ACQUISITION OF WEATHER INFORMATION

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2137		(TA297 crosses London, Ontario, VOR (YXU) at FL390.)	
		(Based on the latest Chicago weather, as received from BUF Flight Watch, TA297 decides to check weather at the alternate, MKE, should diversion to the alternate become necessary. The crew does this to make sure that MKE's weather has not deteriorated and that it is still a viable "out" if ORD's weather gets worse. TA297 contacts London, Ontario, Radio for desired weather data.)	
	AG	"LONDON RADIO, TRANSAIR 297 HEAVY, FREQUENCY 126.7."	• Flight Service Stations monitor a number of different frequencies. On initial call, TA297 indicates the frequency it is using so FSS specialist knows on which one to respond.
	GA	"TRANSAIR 297 HEAVY, THIS IS LONDON RADIO, GO AHEAD."	

TABLE A-17
(Concluded)

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2138	AG	"ROGER LONDON RADIO, TRANSAIR 297 HEAVY OVER LONDON FL390, HEAVY DC10, IFR CHICAGO, REQUEST LATEST CHICAGO AND MILWAUKEE WEATHER AND FORECASTS FOR NEXT FOUR HOURS."	• TA297, while in the process of requesting MKE weather, issues another request for ORD weather to see if any changes have occurred since it talked with Buffalo Flight Service.
	GA	"TRANSAIR 297, I HAVE YOUR REQUEST, PLEASE STAND BY."	• FSS specialist rounds up information from the teletypes.
	GA	"TRANSAIR 297 HEAVY, ARE YOU READY TO COPY?"	• FSS specialist alerts crew to prepare to copy the following information.
	AG	"YES, SIR, GO AHEAD FOR TRANSAIR 297 HEAVY."	
	GA	"CHICAGO-O'HARE WEATHER AT 2055 ZULU MEASURED 900 OVERCAST, VISIBILITY 2 RAINSHOWERS, FOG, TEMPERATURE 71^{0} DEWPOINT 70^{0} WIND 300 AT 8 ALTIMETER 29.85. O'HARE FORECAST THROUGH 0100 ZULU 1000 OVERCAST 3 MILES RAIN AND FOG, CHANCE OF 500 OVERCAST 1 MILE RAIN AND FOG. MILWAUKEE 2047 ZULU OBSERVATION 1500 OVERCAST 4 MILES LIGHT RAIN, TEMPERATURE 67 DEWPOINT MISSING, WIND 280 AT 7, ALTIMETER 29.82. MILWAUKEE FORECAST THROUGH 0300 ZULU 1500 OVERCAST, 5 MILES LIGHT RAIN."	• FSS specialist parcels out the weather information according to location so crew can make comparison of current conditions and forecast.
	AG	"LONDON RADIO, TRANSAIR 297 HEAVY COPIES ALL THAT, THANK YOU."	

TABLE A-18
STANDARD COMMUNICATIONS HANDOFF

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2143	GA	"TRANSAIR 297 HEAVY, CONTACT CLEVELAND CENTER ON 128.9, GOODDAY."	
	AG	"TRANSAIR 297 HEAVY SWITCHING TO 128.9 GOODDAY."	
	AG	"CLEVELAND CENTER, TRANSAIR 297 HEAVY, LEVEL FL390."	
	GA	"TRANSAIR 297 HEAVY, GOODAFTERNOON, THIS IS CLEVELAND CENTER."	
2147		(TA297 crosses Peck VOR (ECK) at FL390.)	
2154		(TA297 crosses Flint VOR (FNT) at FL390.)	

TABLE A-19
PILOT/ATC RESOLUTION OF TRAFFIC CONFLICT

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2155	GA	"TRANSAIR 297 HEAVY, TURN RIGHT HEADING 300 FOR TRAFFIC."	• Controller has issued a heading which will take TA297 off the planned route.
	AG	"CENTER, TRANSAIR 297 HEAVY WILL TAKE A DESCENT TO FL350, IF THAT WILL HELP."	• Crew desires to stay on route; offers to descend to resolve traffic conflict.
	GA	"YES, TRANSAIR 297 HEAVY, THAT WILL HELP, STAY ON J547, DESCEND AND MAINTAIN FL350."	• Controller ammends last instruction with "stay on J547", and issues descent clearance.
	AG	"TRANSAIR 297 HEAVY, ROGER, LEAVING FL390 FOR FL350."	• TA297 acknowledges descent clearance, and reports leaving FL390 as required by procedures.

TABLE A-20
STANDARD COMMUNICATIONS HANDOFF

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2203	GA	"TRANSAIR 297 HEAVY, CONTACT CHICAGO CENTER NOW ON FREQUENCY 133.7, GOODDAY."	
	AG	"TRANSAIR 297 HEAVY TO 133.7, GOODDAY."	
	AG	"HELLO CHICAGO CENTER, TRANSAIR 297 HEAVY, LEVEL FL350."	• Standard check-in.
	GA	"TRANSAIR 297 HEAVY, CHICAGO CENTER, GOOD AFTER-NOON."	

TABLE A-21
ACQUISITON OF ARRIVAL ATIS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2204	GA	(While monitoring the assigned ATC frequency, TA297 picks up the Chicago O'Hare ATIS on frequency 135.15 MHz.) "CHICAGO O'HARE AIRPORT INFORMATION JULIET: 2150 COORDINATED UNIVERSAL TIME WEATHER - 2000 OVERCAST VISIBILITY 4 MILES IN LIGHT RAIN AND FOG, TEMPERATURE 78 DEWPOINT 71, WIND 250 DEGREES AT 9, ALTIMETER 29.96. SIMULTANEOUS ILS APPROACHES 27 LEFT AND RIGHT. LANDING 27 LEFT AND RIGHT. DEPARTING 27 LEFT AND 32 LEFT. ADVISE YOU HAVE JULIET."	• Crew copies down ATIS information and uses the information as follows: - The approach and runway data permit the crew to retrieve the applicable charts and set up the nav radios. - The weather data let the crew anticipate when it will have visual contact on the approach. - Temperature/pressure data used to calculate go-around thrust settings from performance manuals or a flight management system.

C-2

TABLE A-22
INITIAL DESCENT INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2206	GA	"TRANSAIR 297 HEAVY, DESCEND AND MAINTAIN FL200."	
	AG	"TRANSAIR 297 HEAVY LEAVING FL350 FOR FL200."	
2210		(TA297 crosses Pulman VOR (PMM) at FL290 in a descent to FL200.)	
2212	GA	"TRANSAIR 297 HEAVY, CONTINUE DESCENT TO 16,000, IF POSSIBLE GIVE ME A GOOD RATE. CHICAGO O'HARE ALTIMETER 29.96."	• Even before TA297 reaches last assigned altitude, controller issues instructions for further descent, and requests a steep descent. Altimeter setting always provided on first descent assignment below 18,000 feet.
	AG	"TRANSAIR 297 HEAVY, THROUGH FL260 FOR 16,000 AND WE'LL MAINTAIN A GOOD RATE."	• TA297 will comply with all requests.

TABLE A-23
STANDARD COMMUNICATIONS HANDOFF AND
INITIAL APPROACH INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2216	GA	"TRANSAIR 297 HEAVY, CONTACT CHICAGO APPROACH ON 125.0, GOODDAY."	
	AG	"TRANSAIR 297 HEAVY, SWITCHING TO APPROACH ON 125.0, GOODDAY."	
	AG	"CHICAGO APPROACH, TRANSAIR 297 HEAVY WITH YOU LEVEL 16,000 WITH JULIET."	
	GA	"TRANSAIR 297 HEAVY, CHICAGO APPROACH, SLOW TO 230 KNOTS AND DESCEND TO 10000, PLAN ON VECTORS FOR THE ILS TO 27 RIGHT."	
	AG	"SLOWING TO 230, LEAVING 16000 FOR 10000, TRANSAIR 297 HEAVY ROGER."	

TABLE A-24
COMPANY ARRIVAL PLANNING COMMUNICATIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2217		(While monitoring Chicago Approach frequency TA297 calls the Transair Ramp at Chicago to inform them of TA297's estimated arrival time and to obtain a gate assignment.)	
	AG	"TRANSAIR RAMP, TRANSAIR 297 HEAVY."	
	GA	"TRANSAIR 297 HEAVY, THIS IS CHICAGO RAMP , GO AHEAD."	
	AG	"TRANSAIR 297 HEAVY ESTIMATES ON AT 2232."	
	GA	"ROGER TRANSAIR 297 HEAVY, ESTIMATING ON AT 32, PLAN ON GATE F-7."	
	AG	"TRANSAIR 297 HEAVY WILL MEET YOU AT GATE F-7."	

TABLE A-25
TERMINAL AREA MANEUVERING INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2219	GA	"TRANSAIR 297 HEAVY DEPART MAROW ON THE HEADING 210°, VECTORS FOR THE ILS 27 RIGHT APPROACH."	• On the first vector which takes the flight off of a published route, the controller will indicate the objective of the vectors (e.g. "vectors for the ILS") so the crew will know what to do should radio communications be lost.
	AG	"LEAVE MAROW ON A HEADING OF 210°, TRANSAIR 297 HEAVY."	• TA297 acknowledges receipt and will comply.
2221		(TA297 crosses MAROW intersection and turns to 210° as instructed.)	
2223	GA	"TRANSAIR 297 HEAVY, DESCEND AND MAINTAIN 6000."	
	AG	"TRANSAIR 297 HEAVY IS LEAVING TEN FOR SIX."	

TABLE A-25
(Concluded)

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2226	GA	"TRANSAIR 297 HEAVY, SLOW TO 200 KNOTS, RIGHT TO HEADING 240°, DESCEND AND MAINTAIN 4000."	
	AG	"REDUCING TO 200, RIGHT TO 240°, LEAVING 6000 FOR 4000, TRANSAIR 297 HEAVY WILCO."	
	GA	"AND TRANSAIR 297 HEAVY, ON THAT HEADING INTERCEPT THE 27 RIGHT LOCALIZER AND FLY IT INBOUND."	• This instruction could have been appended to controller's last transmission but the volume of information was getting large; therefore the controller decided to break up the instructions into blocks.
	AG	"INTERCEPT AND FLY INBOUND, TRANSAIR 297 HEAVY."	

TABLE A-26
FINAL APPROACH CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2229	GA	"TRANSAIR 297 HEAVY, WHAT WILL YOUR FINAL APPROACH SPEED BE?"	• When it is necessary to issue speed commands to aircraft for spacing control, the controller cannot ask the aircraft to reduce speed below the final approach speed (which varies from aircraft to aircraft). In this question, the controller is determining how much control he has over TA297's speed.
	AG	"IT'LL BE ABOUT 150 KNOTS, TRANSAIR 297 HEAVY."	
	GA	"TRANSAIR 297 HEAVY, SLOW TO APPROACH SPEED: YOU'RE 8 MILES FROM TAFFS, CLEARED FOR THE ILS 27 RIGHT APPROACH, MAINTAIN 4000 UNTIL ESTABLISHED ON THE LOCALIZER."	• Navigation responsibility is now back to the crew; controller indicates aircraft position for orientation purposes.
	AG	"WE ARE REDUCING SPEED AND CLEARED FOR THE APPROACH, TRANSAIR 297 HEAVY."	

TABLE A-27
LANDING CLEARANCE AND TAXI INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2233	GA	"TRANSAIR 297 HEAVY, CONTACT TOWER NOW ON 118.1."	
	AG	"TRANSAIR 297 TO 118.1, GOODDAY."	
	AG	"TOWER, TRANSAIR 297 HEAVY'S WITH YOU."	
	GA	"TRANSAIR 297 HEAVY, CHICAGO TOWER, YOU'RE CLEARED TO LAND 27 RIGHT."	
	AG	"CLEARED TO LAND, TRANSAIR 297 HEAVY."	
2235		(TA297 lands on 27 right.)	
	GA	"TRANSAIR 297 HEAVY, NEXT LEFT TURN, CONTACT GROUND POINT NINE."	
	AG	"TRANSAIR 297 HEAVY ROGER."	
	AG	"CHICAGO GROUND, TRANSAIR 297 IS WITH YOU FOR GATE F-7."	
	GA	"TRANSAIR 297 TAXI VIA THE OUTER TO F-7."	
	AG	"TRANSAIR 297, ROGER."	

TABLE A-28
COMPANY LANDING/ARRIVAL NOTICE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2236		(While taxing in, TA297 monitors Ground Control and contacts Transair Ramp to alert ground crew of imminent arrival at gate.)	
	AG	"TRANSAIR RAMP, 297's ON AT 35, FOR GATE F-7."	
	GA	"297, ROGER, GATE F-7."	

A.2 Background Information on the ORD-DEN Segment

For the ORD-DEN segment, it is assumed that the flight plan filed in advance for TA297 is as follows:

Identification: TA297
Aircraft Type and Equipment: H/DC10/A
True Airspeed: 475 Knots
Departing: ORD
Proposed Departure Time: 2344 UCT (1844 CDT)
Cruising Altitude: FL390
Route of Flight:

ORD7.ORD.DBQ.J94.ONL.J114......DEN

(Read as O'Hare 7 Departure to Dubuque VOR J94 to O'Neill VOR J114 to Denver)

Estimated Time En Route: 2:10
Alternate Airports: None

Discussion: The route in the flight plan filed by TA297 is slightly different from the High Altitude Preferred Route currently active in the ATC system between ORD and DEN. The assumption is made that TA297 has a reason for filing this specific route (such as cost, or reported turbulence on the ATC-preferred route). However, the ATC system, not being sensitive to the external factors which prompted TA297 to consider a non-preferred route, will clear the flight on its active preferred route between ORD and DEN as follows:

ORD.IOW.DSM.J10......DEN

(Read as direct to Iowa City VOR direct to Des Moines VOR J10 to Denver).

For the purpose of illustration, it is again assumed that TA297 accepts the clearance as received (including the ATC-preferred route) as a means of getting into the air on schedule. Submitting another flight plan or negotiating the clearance would likely delay the flight. Once airborne, however, TA297 will submit requests to modify the clearance to bring the route to closer conformance with the route it originally filed. This is a common practice in today's ATC system and provides a useful illustration of a potential application of data link from a systems concept viewpoint.
Figure A-3 depicts the route filed by TA297, the route as originally cleared by ATC, and the subsequent revised clearance given to TA297 after it became airborne.

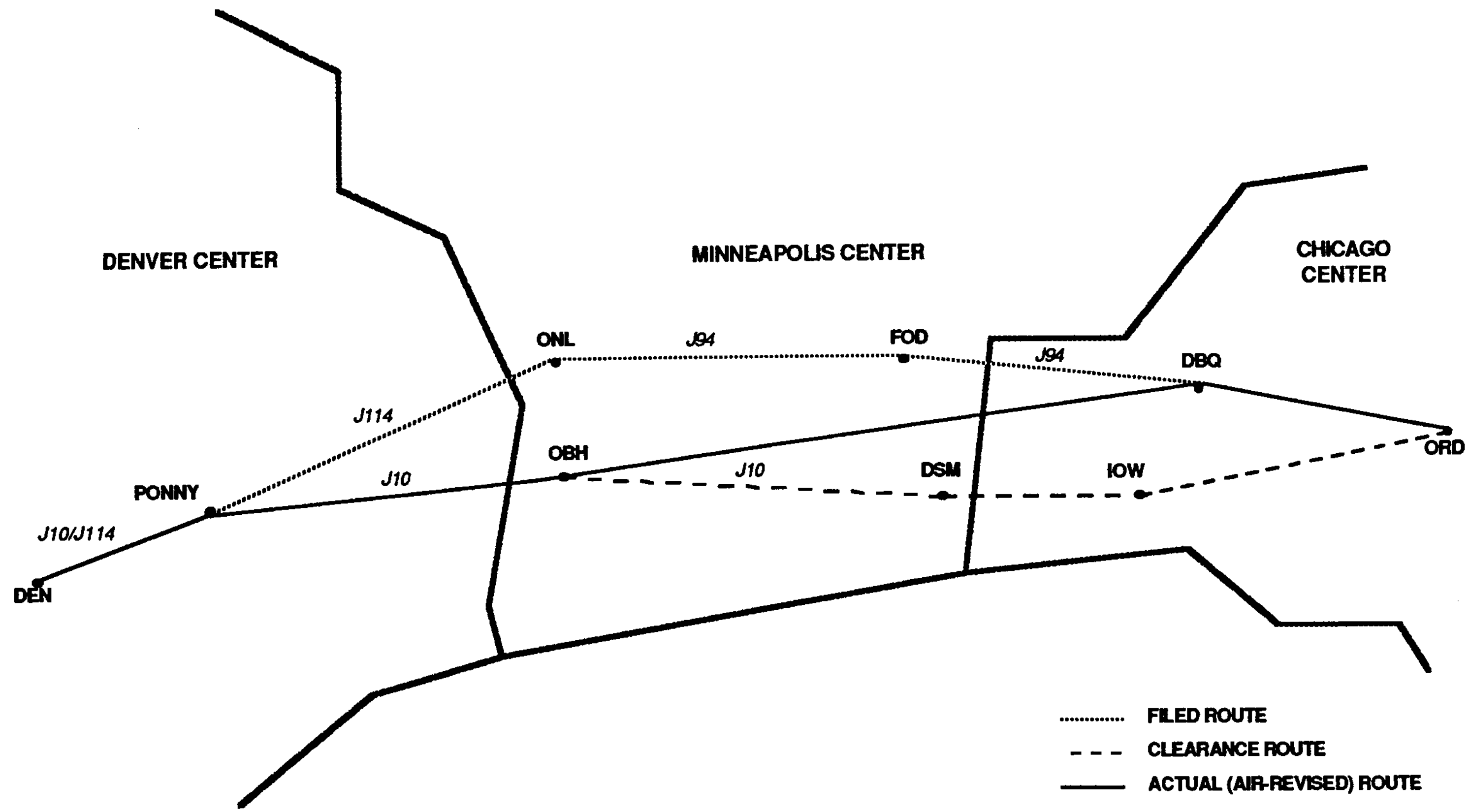

FIGURE A-3
FILED AND ACTUAL ROUTE FOR TA297 ORD-DEN

TABLE A-29
ACQUISITION OF DEPARTURE ATIS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2315	GA	(Repetitive broadcast of ATIS information in coverage volume on 135.15 MHz). "CHICAGO O'HARE AIRPORT INFORMATION LIMA: 1745 COORDINATED UNIVERSAL TIME WEATHER - 3000 OVERCAST VISIBILITY 5 MILES LIGHT RAIN TEMPERATURE 78, DEWPOINT 70 WIND 260 DEGREES AT 10 KNOTS ALTIMETER 29.98 SIMULTANEOUS ILS APPROACHES RUNWAY 27 LEFT AND RIGHT LANDING RUNWAYS 27 LEFT AND RIGHT DEPARTING RUNWAYS 27 LEFT 32 LEFT NOTAMS: 32 LEFT DEPARTURES FROM TAXIWAY 1, 8800 FEET AVAILABLE; 9 RIGHT - 27 LEFT PARALLEL TAXIWAY CLOSED BETWEEN BRANCH AND NORTH/SOUTH TAXIWAY; CONSTRUCTION ON ALL RAMPS -USE CAUTION; ADVISE YOU HAVE LIMA."	• Provides aircrews with most recent weather and airport conditions and current airport operating configuration. • Departing crews use weather and runway data for takeoff performance planning; also use runway data to anticipate departure routing to en route fix. • Notams describe temporary conditions of interest to crew; occasionally long and difficult to to copy; therefore, crew usually makes a written copy of only the weather/runway data.

TABLE A-30
REQUESTING/RECEIVING IFR CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2325		(TA297 issues request for clearance to DEN on frequency 121.6 MHz.)	
	AG	O'HARE CLEARANCE DELIVERY, TRANSAIR 297 HEAVY, GATE F7 WITH LIMA, REQUEST CLEARANCE TO DENVER."	• Crew addresses ORD Clearance, states position on field, acknowledges receipt of latest airport information and ready to copy down ATC clearance
	GA	"TRANSAIR 297 HEAVY, ROGER, STANDBY."	• ORD Clearance acknowledges request, instructs TA297 to monitor the the frequency for issuance of clearance when available.
	AG	"TRANSAIR 297 HEAVY."	• TA297 acknowledges receipt of last transmission.
		. . . .	
2327	GA	"TRANSAIR 297 HEAVY, I HAVE YOUR CLEARANCE WHEN YOU ARE READY TO COPY."	• Informs crew to be ready to copy the following information.
	AG	"TRANSAIR 297 HEAVY IS READY TO COPY."	

TABLE A-30
(Concluded)

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2327	GA	"TRANSAIR 297 HEAVY CLEARED TO DENVER VIA O'HARE SEVEN DEPARTURE IOWA CITY, DES MOINES, J-10, MAINTAIN FL390. DEPARTURE FREQUENCY 125.4, SQUAWK 4614."	• ATC clears flight on its ATC-preferred route from ORD-DEN. It includes a SID which contains step-climb and radar vector instructions.
	AG	"CLEARANCE, TRANSAIR 297 HEAVY WILL HAVE TO CHECK THAT ROUTING."	• The clearance is not what TA297 had filed; therefore, the crew must review the routing to see if it is acceptable. This transmission informs ORD Clearance that TA297 will not read back the clearance until the routing is reviewed and approved by the crew. (Assume the clearance is initially acceptable to TA297, although it will seek amendments once en route.)
	AG	"O'HARE CLEARANCE, TRANSAIR 297 HEAVY UNDERSTANDS CLEARED TO DENVER VIA O'HARE SEVEN, IOWA CITY, DES MOINES, J-10, MAINTAIN FL390, 125.4, 4614."	• TA297 reads back all of clearance to indicate acceptance
	GA	"TRANSAIR 297 HEAVY, READ BACK CORRECT, CONTACT GROUND 121.9"	• ATC system will maintain this clearance unless later modified.
	AG	"TRANSAIR 297 HEAVY ROGER."	• TA297 concludes communication w/ ORD clearance; signs off of frequency.

TABEL A-31
TAXI INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2350		(TA297 requests taxi instructions on frequency 121.9)	
	AG	"O'HARE GROUND, TRANSAIR 297 HEAVY, TAXI FROM F-7 WITH CLEARANCE."	• TA297 indicates ready to taxi and states position on field so ground control can acquire visually and issue instructions.
	GA	"TRANSAIR 297 HEAVY, O'HARE GROUND, TAXI TO RUNWAY 32 LEFT VIA THE STUB AND THE 9 LEFT/27 RIGHT PARALLEL. GIVE WAY TO THE NORTHWEST 747 AND FOLLOW HIM."	
	AG	"TA297 HEAVY, ROGER."	• TA297 acknowledges and will comply.

TABLE A-32
OBTAINING COMPANY TAKEOFF PLANNING DATA

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2351		(TA297 calls Transair Ramp radio on 129.3 MHz to obtain final weight and fuel data)	
	AG	"TRANSAIR RAMP, TRANSAIR 297 HEAVY READY TO COPY NUMBERS."	
	GA	"TRANSAIR 297 HEAVY, 25 IN FIRST, 129 IN COACH, TAKEOFF FUEL 64,000, TAKEOFF WEIGHT 354,124, CG 21.9."	• These data include final passenger count, weight, and fuel. Crew uses data for calculation of V-speeds and trim.
2351	AG	"TRANSAIR 297 HEAVY UNDERSTANDS 25, 129, 64000, 354124, 21.9, OUT OF GATE AT F7, ESTIMATE OFF AT 55."	• TA297 reads back the numbers, provides out and estimated off times.
	GA	"TRANSAIR 297, ROGER, GOODDAY."	• Ramp acknowledges numbers correct and receipt of out/off times. • Although TA297 has concluded necessary communications on Ramp frequency, most airlines require crews to monitor the Ramp frequency while the aircraft is on the ground to relay last minute information if necessary.

TABLE A-33
TAKEOFF CLEARANCE AND HANDOFF TO DEPARTURE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2352	GA	"TRANSAIR 297 HEAVY, MONITOR THE TOWER 118.1 AND CALL WHEN YOU ARE NUMBER 1 IN SEQUENCE."	• Ground control builds a queue for 32L departures. Once in queue, TA297 instructed to monitor the tower and call when it advances to #1 position.
	AG	"TRANSAIR 297 HEAVY, ROGER."	• TA297 understands and will comply.
		(TA297 monitors tower on 118.1, advances in sequence to #1 spot.)	
2355	AG	"CHICAGO TOWER, TRANSAIR 297 HEAVY IS #1 FOR DEPARTURE 32 LEFT."	• TA297, as instructed, calls the tower when ready for takeoff.
	GA	"TRANSAIR 297 HEAVY, CHICAGO TOWER, CLEARED FOR TAKEOFF RUNWAY 32 LEFT."	
	AG	"TRANSAIR 297 IS CLEARED FOR TAKEOFF."	• TA297 reads back command.
2356	GA	"TRANSAIR 297 HEAVY, TURN LEFT HEADING 300 DEGREES AND CONTACT DEPARTURE."	• Tower issues initial vector and hands off to departure control.
	AG	"TRANSAIR 297 HEAVY, ROGER, LEFT 300 DEGREES AND GOODDAY."	• TA297 acknowledges the vector, and implies leaving the frequency with "Goodday."

TABLE A-34
INITIAL CHECK-IN AND TACTICAL INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2356		(TA297 switches to frequency 125.4 as assigned in original clearance)	
	AG	"CHICAGO DEPARTURE, TRANSAIR 297 HEAVY IS WITH YOU, HEADING 300 DEGREES, THROUGH 1500 FEET FOR 5000."	• On initial check-in, TA297 provides initial heading and altitude assignments, although it only needs to report the passing altitude (1500). The 5000 feet climb assignment is part of the O'Hare Seven SID. (See Figure A-4.)
	GA	"TRANSAIR 297 HEAVY, CHICAGO DEPARTURE RADAR CONTACT, CLIMB AND MAINTAIN 10,000."	• Departure acknowledges radar contact, which eliminates need for TA297 to issue position reports. Crew understands vectors will be for IOW VOR (unless otherwise stated) because it's part of O'Hare Seven SID. 5000 foot climb restriction now raised to 10,000 feet; 300 degrees heading still applies.
	AG	"TRANSAIR 297 HEAVY, ROGER, THROUGH 2500 TO 10,000."	• TA297 reads back tactical assignments.

OF POOR QUALITY

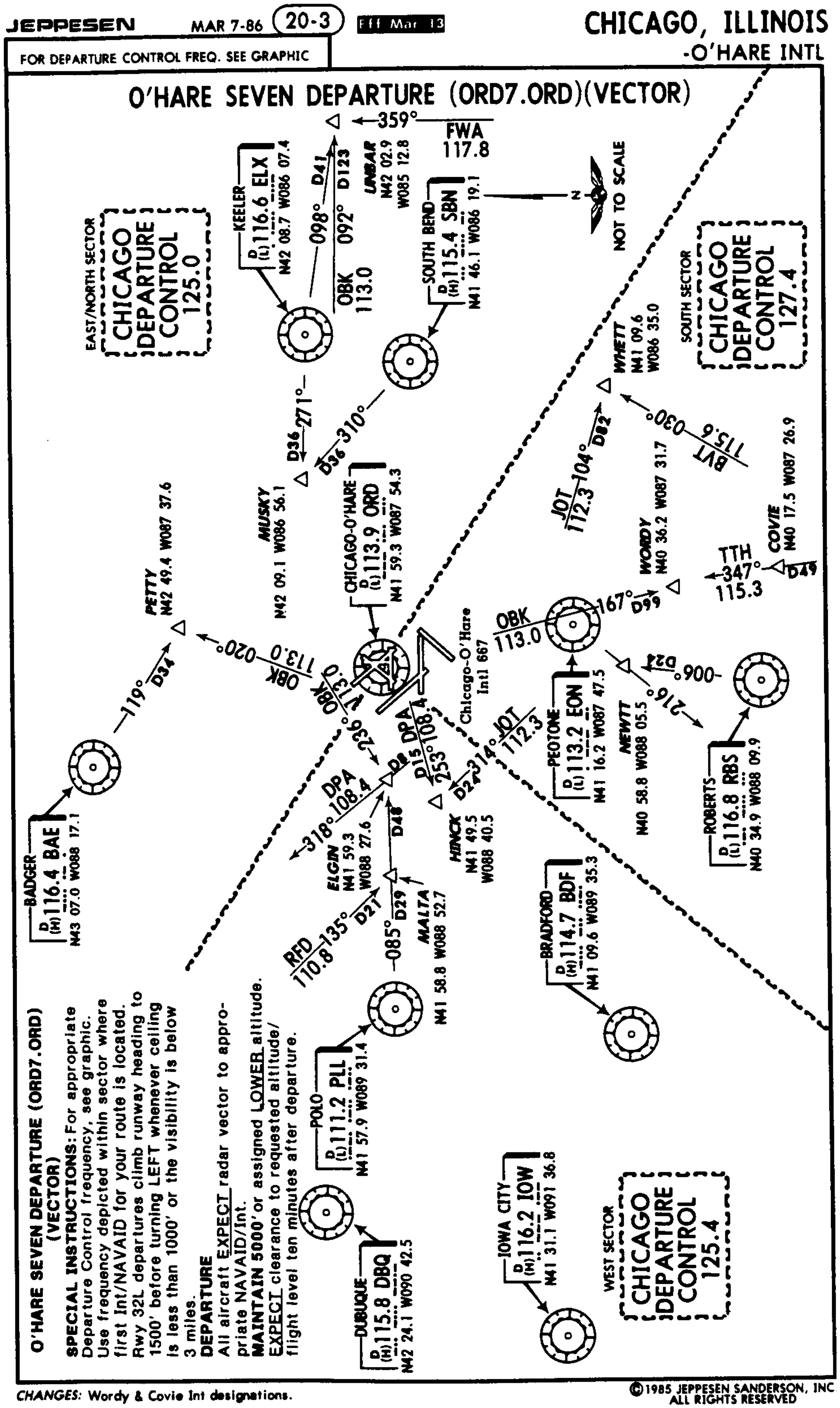

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FIGURE A-4
O'HARE SEVEN STANDARD INSTRUMENT DEPARTURE

TABLE A-35
DEPARTURE AREA TACTICAL INSTRUCTIONS AND TRAFFIC ADVISORY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
2358	GA	"TRANSAIR 297 HEAVY, TURN LEFT HEADING 260; WHEN RECEIVING IOWA CITY VOR PROCEED DIRECT."	• This is last heading instruction for TA297 - it will follow clearance route once it is receiving IOW VOR.
	AG	"TRANSAIR 297 HEAVY UNDERSTAND LEFT HEADING 260 DIRECT IOWA CITY."	
0001	GA	"TRANSAIR 297 HEAVY, YOU HAVE VFR TRAFFIC, 2:00, 4 MILES, SOUTHWESTBOUND, ALTITUDE UNKNOWN."	• Standard traffic advisory for non-controlled VFR traffic.
	AG	"TRANSAIR 297 HEAVY, ROGER, TRAFFIC IN SIGHT DOWN LOW."	• TA297 acknowledges traffic in sight; Chicago Departure will not issue more advisories on this target.

TABLE A-36
STANDARD COMM HAND-OFF AND CHECK-IN

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0002	GA	"TRANSAIR 297 HEAVY, CONTACT CHICAGO CENTER 132.75."	• Standard hand-off to another facility.
	AG	"TRANSAIR 297 HEAVY TO 132.75, GOODDAY."	
		(TA297 switches frequency to 132.75 MHz.)	
	AG	"CHICAGO CENTER, 297 HEAVY IS WITH YOU AT 9000 FOR 10000."	• TA297 checks in and mentions "9000 for 10000" - implying TA297 would like 10000 level restriction removed so it can continue climb.
	GA	"TRANSAIR 297 HEAVY, CHICAGO CENTER."	• Chicago Center acknowledges TA297; radar contact assumed within ATC system unless controller notifies flight that radar contact lost.

TABLE A-37
TRANSMISSION OF OPERATIONS DATA TO COMPANY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0002		(While monitoring the assigned ATC frequency, TA297 files on Out and Off report to TRANSAIR operations.)	
	AG	"TRANSAIR RADIO (or ARINC radio) TRANSAIR 297 HEAVY, OFF REPORT."	• Addresses the facility called and informs them that an "Off" report will be transmitted.
	GA	"TRANSAIR 297, HEAVY, THIS IS TRANSAIR RADIO, GO AHEAD."	• Acknowledgement implies that United radio is ready to copy the information according to accepted "Off" report format.
	AG	"TRANSAIR 297 HEAVY, PLANE 808TA, DEPARTED O'HARE OUT AT 2345 OFF AT 2355 FUEL 64,000, ESTIMATE DENVER AT 0205, OVER."	• Crew transmits the information in sequence according to format. The company uses this information to plan arrival processing and gate assignments for arriving flights. It is also used to update airport TV monitors displaying arrival times.

TABLE A-38
PILOT REQUEST TO REVISE IFR CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0004		(TA297 places request for modification of clearance to bring it to closer conformance with minimum cost route.)	
	AG	"CHICAGO CENTER TRANSAIR 297 HEAVY REQUESTING REVISED ROUTING TO DENVER: DIRECT DUBUQUE J94 O'NEILL J114 DENVER, FL390."	• Crew resubmits its minimum cost route and altitude.
	GA	"TRANSAIR 297 HEAVY I HAVE YOUR REQUEST, STAND BY."	• Chicago Center acknowledges receipt and informs TA297 to wait for response.
	AG	"TRANSAIR 297 HEAVY, ROGER."	• A/C acknowledgement.

TABLE A-39
PILOT ACCEPTANCE OF REVISED ROUTING

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0010	GA	"TRANSAIR 297 HEAVY, O'NEILL VOR IS OUT OF SERVICE. I CAN GIVE YOU DIRECT DUBUQUE J100 WOLBACH J10 DENVER AT FL390."	• The specific route that TA297 requested is not available due to an inoperative navaid. Center offers a similar route in its stead. This is not yet a revised clearance.
	AG	"TRANSAIR 297 HEAVY, WE'LL ACCEPT THAT."	
	GA	"TRANSAIR 297 HEAVY CLEARED TO DENVER VIA DIRECT DUBUQUE J100 WOLBACH J10 DENVER. CLIMB AND MAIN-TAIN FL290 - EXPECT FL390 FOR YOU IN 20 MILES."	• Revised clearance is official here. The final altitude is FL390 but a temporary FL290 restriction is applied.
	AG	"TRANSAIR 297 HEAVY IS CLEARED TO DENVER VIA DIRECT DUBUQUE J100 WOLBACH J10. CLIMB AND MAINTAIN FL290, EXPECT FL390 IN 20 MILES."	• Crew reads back revised clearance, and it now becomes the new route to Denver, replacing the previous route.
	GA	"TRANSAIR 297 HEAVY READBACK IS CORRECT, STEER HEADING 300 UNTIL RECEIVING DUBUQUE THEN DIRECT."	• Center gives TA297 an initial vector to Dubuque.
	AG	"300 DEGREES TO DUBUQUE, TRANSAIR 297 HEAVY, ROGER."	

TABLE A-40
EN ROUTE TACTICAL INSTRUCTION

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0016	GA	"TRANSAIR 297 HEAVY, CLIMB AND MAINTAIN FL390."	• Controller lifts last altitude restriction.
	AG	"TRANSAIR 297 HEAVY, THROUGH 18,000 FOR FL390."	
0024		(TA297 crosses Dubuque VOR (DBQ) at FL260, and continues outbound on J100 while climbing to FL390.)	

TABLE A-41
STANDARD COMM HAND-OFF AND CHECK-IN

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0044	GA	"TRANSAIR 297 HEAVY, CONTACT MINNEAPOLIS CENTER 133.55."	
	AG	"MINNEAPOLIS CENTER ON 133.55, TRANSAIR 297 HEAVY, GOODDAY."	• A/C acknowledges and signs off.
		(TA297 tunes in new frequency as assigned)	
	AG	"MINNEAPOLIS CENTER, TRANSAIR 297 HEAVY IS WITH YOU LEVEL FL390."	• TA297 checks in with next center; announces current altitude as recommended in radio communication procedures.
	GA	"TRANSAIR 297 HEAVY, THIS IS MINNEAPOLIS CENTER, GOOD AFTERNOON."	

TABLE A-42
EXCHANGE OF WEATHER INFORMATION

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
		(Again, while maintaining a listening watch on the assigned ATC frequency, TA297 contacts another FAA facility to obtain weather information and file a pilot report on observed weather conditions.)	
0050	AG	"DES MOINES FLIGHT WATCH, TRANSAIR 297 HEAVY 70 MILES NORTHWEST OF DES MOINES AT FL390."	• Initial call addresses the facility and includes aircraft location so DSM Flight Watch can respond using appropriate remote communications facilities.
	GA	"TRANSAIR 297 HEAVY, THIS IS DES MOINES FLIGHT WATCH, GO AHEAD."	
	AG	"ROGER DES MOINES, TRANSAIR 297 HEAVY REQUESTS LATEST DENVER WEATHER AND TERMINAL FORECAST FOR NEXT FOUR HOURS."	
	GA	"TRANSAIR 297 HEAVY, STAND BY."	• Request received.

TABLE A-42
(Concluded)

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0051	GA	"TRANSAIR 297 HEAVY, DENVER STAPLETON WEATHER AT 2355 ZULU MEASURED CEILING 4000 OVERCAST, VISIBILITY 7 TEMPERATURE 60 DEWPOINT 53 WIND 300 DEGREES AT 12 GUSTS 18 ALTIMETER 29.85. DENVER FORECAST FOR NOW THROUGH 0600Z IS CEILING 3000 OVERCAST 5 MILES WIND 270 DEGREES AT 10, CHANCE OF CEILING 1000 OVERCAST 1 MILE IN THUNDERSTORMS AND RAINSHOWERS."	• Weather specialist uses standard phraseology and sequences to provide requested weather data over the radio. Crew of TA297 copies the information down.
	AG	"TRANSAIR 297 HEAVY COPIES ALL THAT. WE'RE A HEAVY DC-10 ON J100 OVER ASTRO INTERSECTION AT FL390. THE RIDE IS SMOOTH, OUTSIDE TEMPERATURE IS MINUS 55 DEGREES, INS WINDS SHOW 300 AT 65."	• TA297 provides standard pilot report for en route weather conditions.
	GA	"TRANSAIR 297 HEAVY, THANK YOU, LIGHT TURBULENCE REPORTED OVER WOLBACH VOR FROM FL350 THROUGH FL410."	• This information was not requested by the crew but the specialist volunteered it as he suspected TA297 would be interested in it.
	AG	"TRANSAIR 297 HEAVY, ROGER, GOODDAY."	

TABLE A-43
PILOT REQUEST FOR CHANGE IN ALTITUDE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0010		(As the flight nears Wolbach VOR, it encounters light turbulence and inquires to Minneapolis Center about the feasibility of using another altitude.)	
	AG	"MINNEAPOLIS CENTER, THIS IS TRANSAIR 297 HEAVY, WE ARE ENCOUNTERING LIGHT TURBULENCE AT FL390. ARE THERE ANY RIDE REPORTS AT LOWER ALTITUDES?"	• This becomes a pilot report for the Center controller to relay to other aircraft.
	GA	"TRANSAIR 297 HEAVY, MOST OF THE TURBULENCE SEEMS TO BE ABOVE FL350. FL310 WAS REPORTED SMOOTH BY A 727 ABOUT 80 MILES AHEAD."	• Because they are in direct contact with aircraft transitting the airspace, the center controllers usually acquire a "picture" of where the turbulence and other non-desirable weather is.
	AG	"OKAY, WE'D LIKE TO REQUEST FL310."	• This may no longer be minimum cost for the flight, but the potential for a smoother ride is preferred.
	GA	"ROGER, TRANSAIR 297 HEAVY DESCEND AND MAINTAIN FL310."	• New altitude assigned by ATC.
	AG	"TRANSAIR 297 HEAVY LEAVING FL390 FOR FL310."	• Readback confirms crew received new altitude assignment. Report of leaving assigned altitude required by regulation.

TABLE A-44
STANDARD COMM HAND-OFF AND CHECK-IN

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0117		(TA297 crosses Wolbach VOR (OBH) at FL390.)	
0120	GA	"TRANSAIR 297 HEAVY, CONTACT DENVER CENTER ON FREQUENCY 135.2."	• Facility handoff from Minneapolis to Denver Center.
	AG	"TRANSAIR 297 HEAVY, ROGER, 135.2, GOODDAY."	• Receipt and compliance acknowledged.
	AG	"DENVER CENTER TRANSAIR 297 HEAVY WITH YOU AT FL310."	
	GA	"TRANSAIR 297 HEAVY, THIS IS DENVER CENTER, RADAR CONTACT."	

TABLE A-45
FLIGHT PHASE: INITIAL DESCENT

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0130	GA	"TRANSAIR 297 HEAVY, PLAN FOR THE PROFILE DESCENT TO DENVER; THEY'RE LANDING WITH THE 26 LEFT ILS, THUNDERSTORMS IN THE AREA."	• Based on center controller's knowledge of Denver's operating configuration, he advises TA297 on what it can expect as it approaches the terminal airspace. TA297 crew uses this information to retrieve and review appropriate charts, and set up navigation radios as required. (Figure A-5)
	AG	"TRANSAIR 297 HEAVY, ROGER."	

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JEPPESEN OCT 17-86 (10-2) Eff Oct 23

RADAR & DME REQUIRED

PROFILE DESCENT

DENVER, COLO

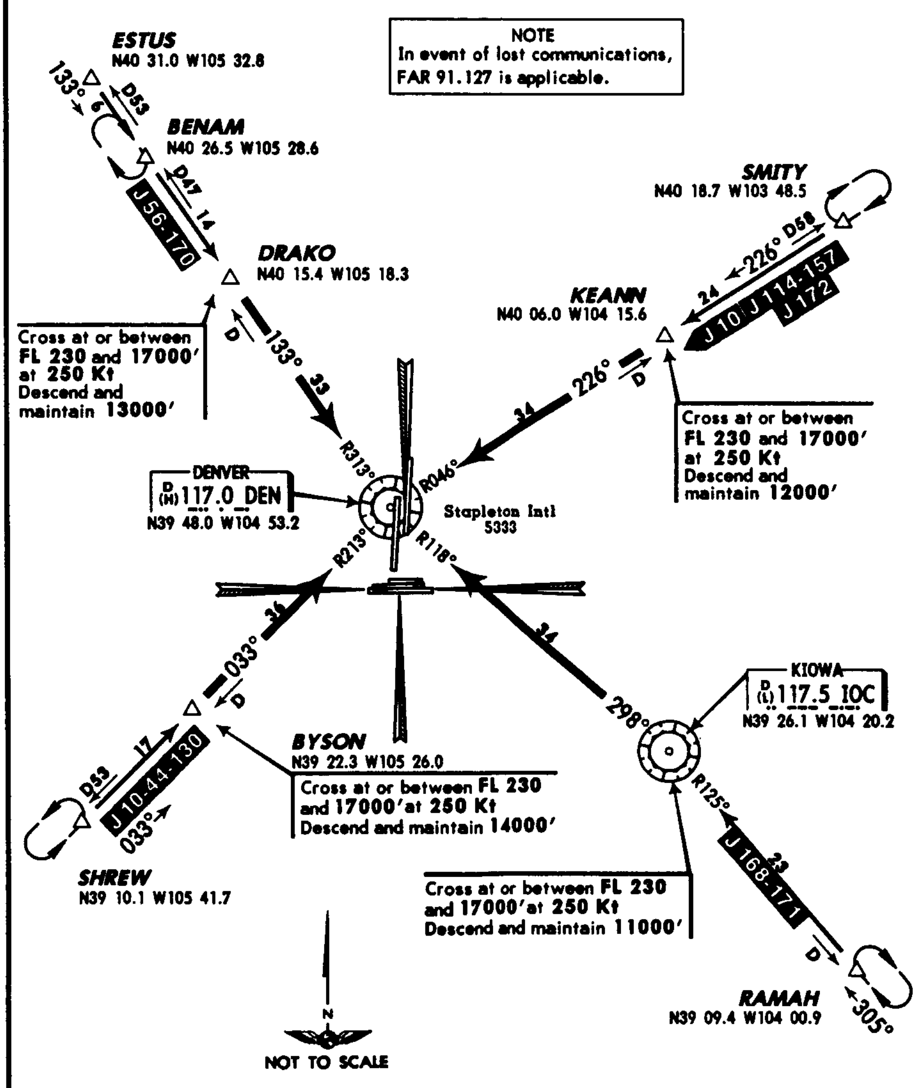
STAPLETON INTL

Rwys 8, 17, 26, 35

EXPECT VECTOR TO FINAL APPROACH PRIOR TO REACHING DENVER VORTAC

FLYING MILES TO RUNWAY

INT	Rwy 8	Rwy 17	Rwy 26	Rwy 35
BENAM	55	55	70	70
RAMAH	75	75	60	60
SHREW	55	75	70	55
SMITY	75	65	60	80



CHANGES: Benam & Shrew Int coordinates.

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FIGURE A-5
DENVER PROFILE DESCENT

TABLE A-46
ACQUISITION OF ARRIVAL ATIS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0135		(TA297 picks up arrival ATIS on frequency 125.6)	
	GA	"DENVER STAPLETON AIRPORT INFORMATION ECHO 0110 UNIVERSAL COORDINATED TIME WEATHER - RECORD SPECIAL MEASURED 900 OVERCAST 3 MILES THUNDERSTORMS AND RAINSHOWERS. TEMPERATURE 59 DEWPOINT 53. WIND 300 DEGREES AT 15 GUSTS 25 ALTIMETER 29.80. ILS APPROACH IN USE RUNWAY 26 LEFT. LANDING 26 LEFT 26 RIGHT. DEPARTING 35 LEFT 35 RIGHT. ADVISE THE CONTROLLER ON INITIAL CONTACT THAT YOU HAVE INFORMATION ECHO."	• ATIS information used by crew for planning arrival into Denver terminal area: - The runway data (approach procedure and landing runways) permit crew to retrieve appropriate charts and tune navigation equipment, - The weather data lets crew anticipate the point on the approach where they can expect to acquire visual contact, - Temperature/pressure data used for calculating go-around thrust from aircraft performance charts or flight management system, - The presence of thunderstorms and low ceilings clues the crew in on potential traffic delays into DEN.

TABLE A-47
COMBINED SPEED AND DESCENT INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0135	GA	"TRANSAIR 297 HEAVY, DESCEND AND MAINTAIN FL260, THEN SLOW TO 250 KNOTS INDICATED.	• Assume that DEN airport acceptance rate is hindered by thunderstorms in the area (necessitating re-routing, deviation requests, etc.). Therefore, TA297 will be given some delay absorbing maneuvers as it approaches DEN. Although it will be assigned the profile descent, modifications to that procedure will be included to meet the needs of the traffic situation.
	AG	"TRANSAIR 297 HEAVY, ROGER, LEAVING FL310 FOR FL260, THEN SLOWING TO 250 KNOTS."	• TA297 acknowledges.

TABLE A-48
COMMUNICATIONS HAND-OFF INVOLVING MISSED ACKNOWLEDGEMENT

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0136	GA	"TRANSAIR 297 HEAVY, CONTACT DENVER CENTER ON 125.95, GOODDAY."	• Handoff to last Center sector on this flight.
		(Assume no acknowledgement from TA297. TA297 may have not received the handoff message, or it may have received it but the acknowledgement never got to the handing-off controller.)	
	GA	"TRANSAIR 297 HEAVY, CONTACT DENVER CENTER 125.95."	• Controller not sure if TA297 received handoff message, so he repeats the message.
		(Assume no contact still)	
	GA	"TRANSAIR 297 HEAVY, HOW DO YOU READ DENVER CENTER?"	• This interrogation implies to the crew that the center has been having trouble communicating with them. If the crew received this transmission, it would respond with the quality of transmissions received from the center indicating that radio communication procedures are still effective.

TABLE A-48
(Concluded)

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
		(Assume no acknowledgement from TA297)	• Center controller still not sure if TA297 has had a radio failure or not. Controller contacts the next sector to see if TA297 has "checked-in" on next frequency. Assume TA297 has checked-in and this potential communications problem is resolved. The root of this problem is either that TA297 did not acknowledge receipt of handoff instruction, or that TA297 acknowledged receipt but the controller did not notice it.
		(TA297 checks-in on assigned frequency 125.95)	
	AG	"DENVER CENTER, TRANSAIR 297 HEAVY WITH YOU THROUGH FL290 FOR FL260."	
	GA	"TRANSAIR 297 HEAVY, DENVER CENTER, ROGER."	

TABLE A-49
PROFILE DESCENT CLEARANCE AND COMM HAND-OFF

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0140	GA	"TRANSAIR 297 HEAVY, CLEARED FOR THE PROFILE DESCENT. DESCEND AND MAINTAIN 12,000. DENVER ALTIMETER 29.80."	• The profile descent basically consists of a "user-planned" descent where the aircraft is given leeway in the crossing altitudes at certain fixes. The local altimeter setting is always given when the aircraft is first instructed to descend below FL180.
	AG	"TRANSAIR 297 HEAVY, ROGER, LEAVING FL270 FOR 12,000, ON THE PROFILE DESCENT."	• TA297 acknowledges.
0145	GA	"TRANSAIR 297 HEAVY CONTACT DENVER APPROACH ON 120.5."	
	AG	"TRANSAIR 297 HEAVY, ROGER, 120.5."	

TABLE A-50
STANDARD COMM CHECK-IN

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0148		(TA297 tunes in assigned frequency of 120.5 MHz).	
	AG	"DENVER APPROACH, TRANSAIR 297 HEAVY WITH YOU THROUGH FL260 ON THE PROFILE, 250 KNOTS ASSIGNED, WITH INFORMATION ECHO."	• TA297 provides next controller with current altitude (FL260), plus the fact that it is carrying a 250 knot speed restriction from the last controller. The flight would normally descend at a faster speed and mentions this restriction as a reminder that a higher speed would be preferred. Also, TA297 acknowledges it has ATIS information "Echo."
	GA	"TRANSAIR 297 HEAVY, DENVER APPROACH, ROGER, INFORMATION FOXTROT IS NOW CURRENT."	• Approach controller acknowledges and advises crew that revised ATIS information now available.

TABLE A-51
ACQUISITION OF REVISED ARRIVAL ATIS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0149		(TA297 again maintains listening watch on assigned ATC frequency while monitoring the ATIS frequency for new airport weather data.) "DENVER STAPLETON INFORMATION FOXTROT 0145 UNIVERSAL COORDINATED TIME WEATHER MEASURED 2500 OVERCAST VISIBILITY SEVEN. TEMPERATURE 56 DEWPOINT 51, WIND 290 DEGREES AT 12 GUSTS 20 ALTIMETER 29.81 ILS APPROACH IN USE RUNWAY 26L LANDING RUNWAY 26 LEFT 26 RIGHT DEPARTING 35 LEFT 35 RIGHT ADVISE YOU HAVE FOXTROT."	 ● Crew copies down revised ATIS. Important changes are improved ceiling and visibility (but flight may still encounter storm cells in the area), and new altimeter setting.

TABLE A-52
REVISED DESCENT AND HOLDING INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0149	GA	"TRANSAIR 297 HEAVY, AMEND YOUR DESCENT TO 17,000 AND I HAVE HOLDING INSTRUCTIONS FOR YOU WHEN YOU ARE READY TO COPY."	• TA297 now told to level-off at 17,000, and receives notice that holding will be necessary and that it should prepare to copy the instructions.
	AG	"TRANSAIR 297 HEAVY WILL LEVEL OFF AT 17,000 AND WE ARE READY TO COPY."	
	GA	"TRANSAIR 297 HEAVY HOLD AT SMITY INTERSECTION AS PUBLISHED, 15 MILE LEGS, EXPECT FURTHER CLEARANCE AT 0205, TIME NOW 0150."	• Standard phraseology for issuance of holding instruction includes an EFC time for use in case of radio communication failure.
	AG	"TRANSAIR 297 HEAVY UNDERSTANDS HOLD AT SMITY AS PUBLISHED, 15 MILE LEGS, EXPECT FURTHER CLEARANCE AT 0205, AND WE'D LIKE TO HOLD AT 250 KNOTS INDICATED FOR TURBULENCE."	• TA297 reads back instructions and requests a holding speed which requires ATC approval (since it exceeds the FAA max hold speed of 230 knots).
	GA	"TRANSAIR 297 HEAVY, 250 KNOTS IS APPROVED."	• TA297 granted request for higher holding speed.

TABLE A-53
REPORTING IN HOLD AND COMPANY DELAY MESSAGE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0157	AG	"DENVER APPROACH, TRANSAIR 297 HEAVY ENTERING THE HOLD AT SMITY, LEVEL 17,000."	• TA297 issues the standard hold entry report (required in both radar and non-radar environments).
	GA	"TRANSAIR 297 HEAVY, ROGER, THANK YOU."	• ATC acknowledges.
		(While maintaining listening watch on assigned Denver Approach frequency, TA297 contacts TRANSAIR ramp for gate information and to advise them of a ten-minute delay anticipated in holding.)	
	AG	"TRANSAIR RAMP, TRANSAIR 297 HEAVY, DELAY REPORT."	
	GA	"TRANSAIR 297 HEAVY, THIS IS TRANSAIR RAMP, GO AHEAD."	
	AG	"TRANSAIR RAMP, 297 HEAVY ESTIMATES ON AT 0225, AND READY FOR GATE ASSIGNMENT."	
	GA	"TRANSAIR 297 HEAVY, ROGER, UNDERSTAND 0225 AND YOU CAN PLAN ON GATE B7."	
	AG	"TRANSAIR 297 HEAVY UNDERSTAND B7, THANK YOU."	

TABLE A-54
INSTRUCTIONS TO CONTINUE PROFILE DESCENT

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0204	GA	"TRANSAIR 297 HEAVY, TURN INBOUND TO SMITY NOW, CONTINUE PROFILE DESCENT, DESCEND AND MAINTAIN 12,000."	• Based on radar track, approach controller "calls" the final turn inbound in TA297's holding pattern so as to have TA297 cross Smity intersection at the desired time. TA297 instructed to proceed inbound on the profile descent.
	AG	"TRANSAIR 297 HEAVY, ROGER, LEAVING 17,000 FOR 12,000."	• TA297 acknowledges receipt and compliance.
	GA	"AND TRANSAIR 297 HEAVY PLEASE MAINTAIN 230 KNOTS ON THE DESCENT FOR IN-TRAIL SPACING."	
	AG	"TRANSAIR 297 HEAVY, WILCO."	

TABLE A-55
REQUEST FOR DEVIATION AROUND WEATHER

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0210	AG	"DENVER APPROACH, TRANSAIR 297 HEAVY REQUESTING DEVIATION 3 MILES TO NORTHWEST OF COURSE FOR WEATHER."	• As TA297 descends into Denver, it needs to detour around thunderstorms it has detected on radar or spotted visually.
	GA	"TRANSAIR 297 HEAVY THAT DEVIATION IS APPROVED."	• ATC authorizes proposed detour.
	AG	"TRANSAIR 297 HEAVY, ROGER."	
0212	AG	"TRANSAIR 297 HEAVY, TURN LEFT HEADING 190 DEGREES TO INTERCEPT V160 FLY INBOUND MAINTAIN 12,000."	• ATC provides vectors to get TA297 back on published route.
	GA	"LEFT 190 DEGREES TO V160, DESCENDING TO 12,000, TRANSAIR 297 HEAVY, ROGER."	

TABLE A-56
COMM HAND-OFF AND TERMINAL AREA MANEUVERING

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0214	GA	"TRANSAIR 297 HEAVY, CONTACT DENVER APPROACH 125.7."	• Handoff to final approach controller.
	AG	"TRANSAIR 297 HEAVY TO 125.7, ROGER."	
		(TA297 switches to assigned frequency)	
0215	AG	"DENVER APPROACH, TRANSAIR 297 HEAVY WITH YOU LEVEL 12,000."	• TA297 checks in.
	GA	"TRANSAIR 297 HEAVY, ROGER RADAR CONTACT, REDUCE TO 210 KNOTS, DEPART FLOTS ON A HEADING OF 150, VECTORS FOR THE ILS 26 LEFT APPROACH."	• ATC acknowledges check-in, and issues tactical instructions for TA297 to be merged into the final approach stream.
	AG	"SLOWING TO 210 KNOTS, DEPART FLOTS ON 150 HEADING, TRANSAIR 297 HEAVY, ROGER."	• TA297 acknowledges.
		(TA297's Initial Approach for the ILS 26 left approach is shown in Figure A-6.)	

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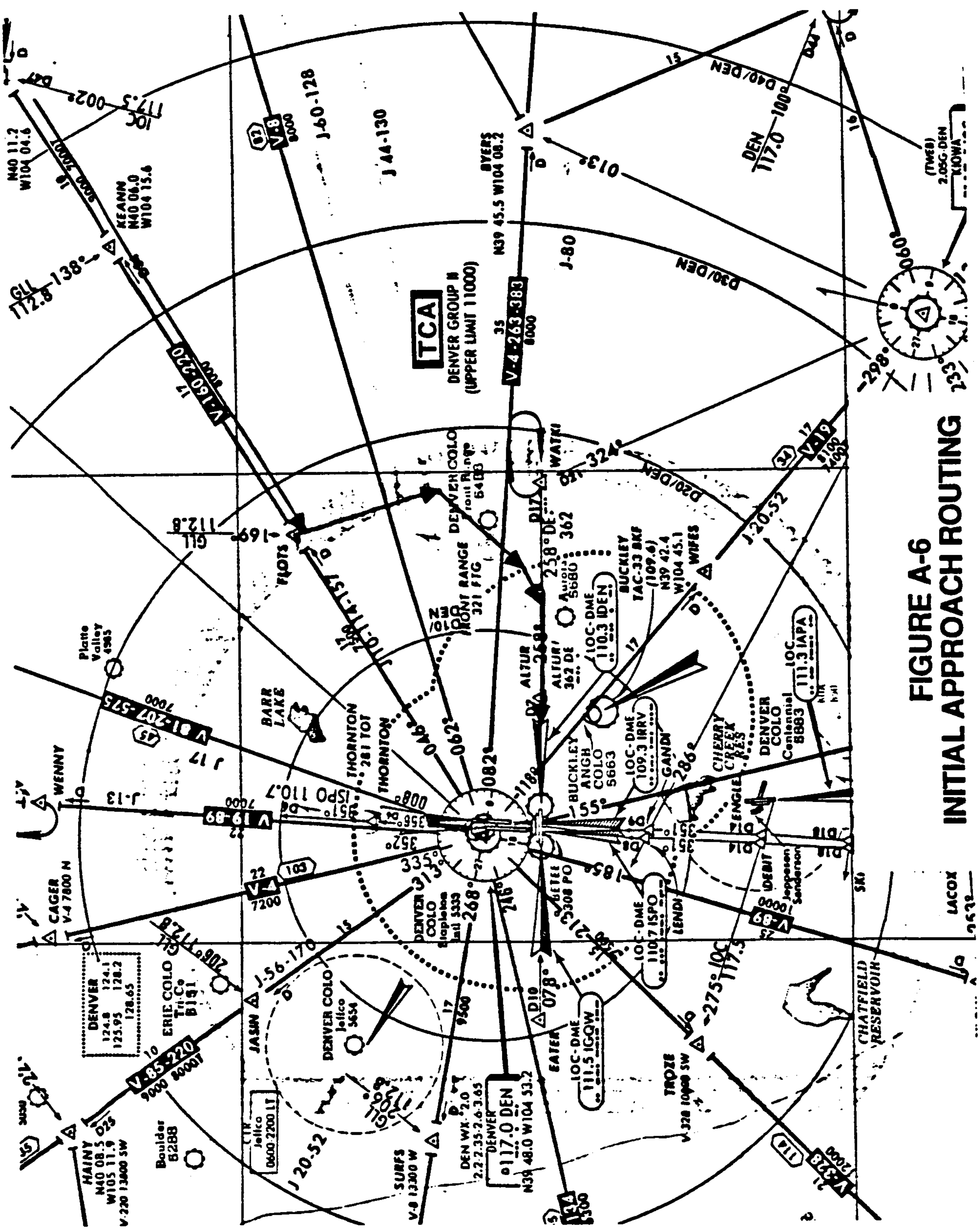

FIGURE A-6
INITIAL APPROACH ROUTING

TABLE A-57
APPROACH MANEUVERING AND FINAL APPROACH CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0217	GA	"TRANSAIR 297 HEAVY, REDUCE TO 190 KNOTS AND RIGHT TO 190 DEGREES, DESCEND AND MAINTAIN 8000."	• Initial approach vectoring.
	AG	"TRANSAIR 297 HEAVY SLOWING TO 190 KNOTS AND RIGHT TO 190 DEGREES, LEAVING 12,000 FOR 8000."	• TA297 acknowledges.
0219	GA	"TRANSAIR 297 HEAVY, YOU ARE 10 MILES NORTHEAST OF ALTUR, TURN RIGHT HEADING 230 DEGREES AND INTERCEPT THE 26 LEFT LOCALIZER; YOU ARE CLEARED FOR ILS 26 LEFT APPROACH, MAINTAIN 8,000 UNTIL ESTABLISHED ON THE LOCALIZER."	• ATC advises TA297 of present position with respect to final approach fix (ALTUR) and issues approach clearance and intercept heading.
	AG	"RIGHT TO 230 DEGREES, CLEARED FOR THE ILS TRANSAIR 297 HEAVY."	• TA297 acknowledges.

TABLE A-58

COMM HAND-OFF AND LANDING CLEARANCE

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0220	GA	"TRANSAIR 297 HEAVY, SLOW TO APPROACH SPEED AND CHANGE OVER TO THE TOWER, 118.3, AT THE OUTER MARKER."	• ATC issues final spacing instruction and gives the aircraft the frequency and point at which to contact Denver Tower.
	AG	"TRANSAIR 297 HEAVY IS SLOWING, AND TOWER 118.3 AT THE MARKER."	• TA297 acknowledges.
0221	AG	"DENVER TOWER, TRANSAIR 297 HEAVY, OUTER MARKER INBOUND.	
	GA	"TRANSAIR 297 HEAVY THIS IS DENVER TOWER, CLEARED TO LAND 26 LEFT; YOUR TRAFFIC IS ON A MILE AND ONE-HALF FINAL."	
	AG	"TRANSAIR 297 HEAVY CLEARED TO LAND."	

TABLE A-59
LOW LEVEL WINDSHEAR ADVISORY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0222		(Denver Tower issues windshear advisories whenever the Low-Level Windshear Alert System (LLWAS) indicates a possible windshear condition.)	
	GA	"TRANSAIR 297 HEAVY, LOW-LEVEL WINDSHEAR ALERT, CENTERFIELD WINDS 310 DEGREES AT 20, EAST BOUNDARY WINDS 270 DEGREES AT 15."	• Tower alerts specific aircraft on approach about possibility of windshear. Tower sometimes issues an "Attention all aircraft" advisory.
	AG	"TRANSAIR 297 HEAVY, ROGER."	

TABLE A-60
CLEARING RUNWAY

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0223		(TA297 completes landing on 26L)	
	GA	"TRANSAIR 297 HEAVY, TURN RIGHT ON CHARLIE-6, HOLD SHORT OF 26R, REMAIN ON THIS FREQUENCY."	• TA297 gets runway clearance instructions from the tower. Because the tower has to coordinate landings on 26R (which TA297 must cross to get to the ramp), it instructs TA297 to remain on his frequency.
	AG	"TRANSAIR 297 HEAVY, ROGER."	
0224	GA	"TRANSAIR 297 HEAVY, CROSS 26R AND CONTACT GROUND ON THE OTHER SIDE 121.9."	
	AG	"TRANSAIR 297 HEAVY, ROGER."	

TABLE A-61
COMPANY ARRIVAL COMMUNICATIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
		(While establishing contact with Denver Ground control, TA297 also contacts TRANSAIR ramp to advise ground personnel that 297 is "on" and to confirm gate assignment.)	
0224	AG	"TRANSAIR RAMP, UNITED 297 HEAVY IS ON AT 0223 FOR GATE B-7."	
	GA	"UNITED 297 ROGER, PROCEED TO GATE B-7, GROUND POWER UNIT WILL BE AVAILABLE."	• Indicates that B7 is the final gate assignment, and informs crew that external power can be used (crew need not start the aircraft's auxiliary power unit
	AG	"TRANSAIR 297, ROGER."	

TABLE A-62
TAXI INSTRUCTIONS

TIME (GMT)	AG GA	INFORMATION CONTENT	REMARKS AND USAGE
0224	AG	"DENVER GROUND, TRANSAIR 297 TO GATE B7."	
	GA	"TRANSAIR 297 HEAVY, DENVER GROUND, PROCEED TO GATE B7."	
	AG	"TRANSAIR 297, WILCO."	

APPENDIX B

DATA LINK COMMUNICATIONS SCENARIO

In this appendix a scenario describing the application of the d/l system concept and procedures is presented. The same basic scenario used to illustrate the r/t communication process in Appendix A is used to illustrate how those exchanges could be accomplished with a communications system augmented by d/l. This scenario is broken down into the two planned segments of the flight, namely BOS-ORD and ORD-DEN, and each segment is developed and presented separately below. The figures which follow describe the postulated flow of information between the air and ground system (including the humans at each end), as well as the events which might take place in the course of normal and abnormal operations.

B.1 TA297 BOS-ORD

As for the r/t scenario, it will be assumed that the flight plan which is reproduced below has been filed in advance with the ATC system for the BOS-ORD segment:

Identification: TA297
Aircraft Type and Equipment: H/DC10/A
True Airspeed: 475 Knots
Departure Station: BOS
Proposed Departure Time: 2015 UCT
Requested Cruising Altitude: FL390
Requested Route of Flight (and Destination):

GDM.CAM.J547.BUF.CRL.SBN.....ORD

Estimated Time En Route: 2:20
Alternate Airports: MKE

Prior to using d/l to communicate with ground facilities, the crew of TA297 must enter the appropriate data into the static portion of the Airborne Message File (AMF, refer to Section 3 for a description of the Communications Management System (CMS) used to facilitate d/l transactions). This initialization process provides reference points on which subsequent d/l transactions can be initiated. The primary data which need to be entered into the static portion of the AMF are the flight plan as originally filed with the ATC system, and the weather station identifiers which will be of interest to the pilot during the proposed flight. Several methods of entering these data into the system are possible, including direct entry by the pilot through a keyboard, or transferring machine-readable copies of the information which have been prepared by a separate flight planning function. (Several commercial vendors of flight planning services, for example, offer the capability to transfer custom-tailored flight plans to the aircraft's navigation database or FMS via disk or magnetic tape.) Regardless of the level of sophistication used in preparing the flight plan, the initialization process can be carried out in the relatively low-workload preflight environment where the pilot has ample time to monitor the loading of the information.

The presentation of this d/l scenario is accomplished by tracing the flow of information from d/l and r/t media through the airborne CMS for transactions that takes place during the course of the flight. Because of the repetitive nature of ATC communications only the first occurrence of each type of data exchange is illustrated. To place these exchanges in their time-sequence perspective, the time (ZULU) and the location of the aircraft when the exchange was initiated is indicated with the descriptive text. Also, company-related communications (such as the filing of Out, Off, On, In reports, obtaining weight and balance and gate information) are not illustrated as their exchange should be tailored to company requirements. However, as evident in the examples provided in Appendix A, company communications lend themselves to ready adaptation to d/l exchange,and in many cases are already performed on d/l using private d/l networks.

A diagram showing the flow of information is presented on the left page, and an accompanying descriptive text is provided on the right, facing page.

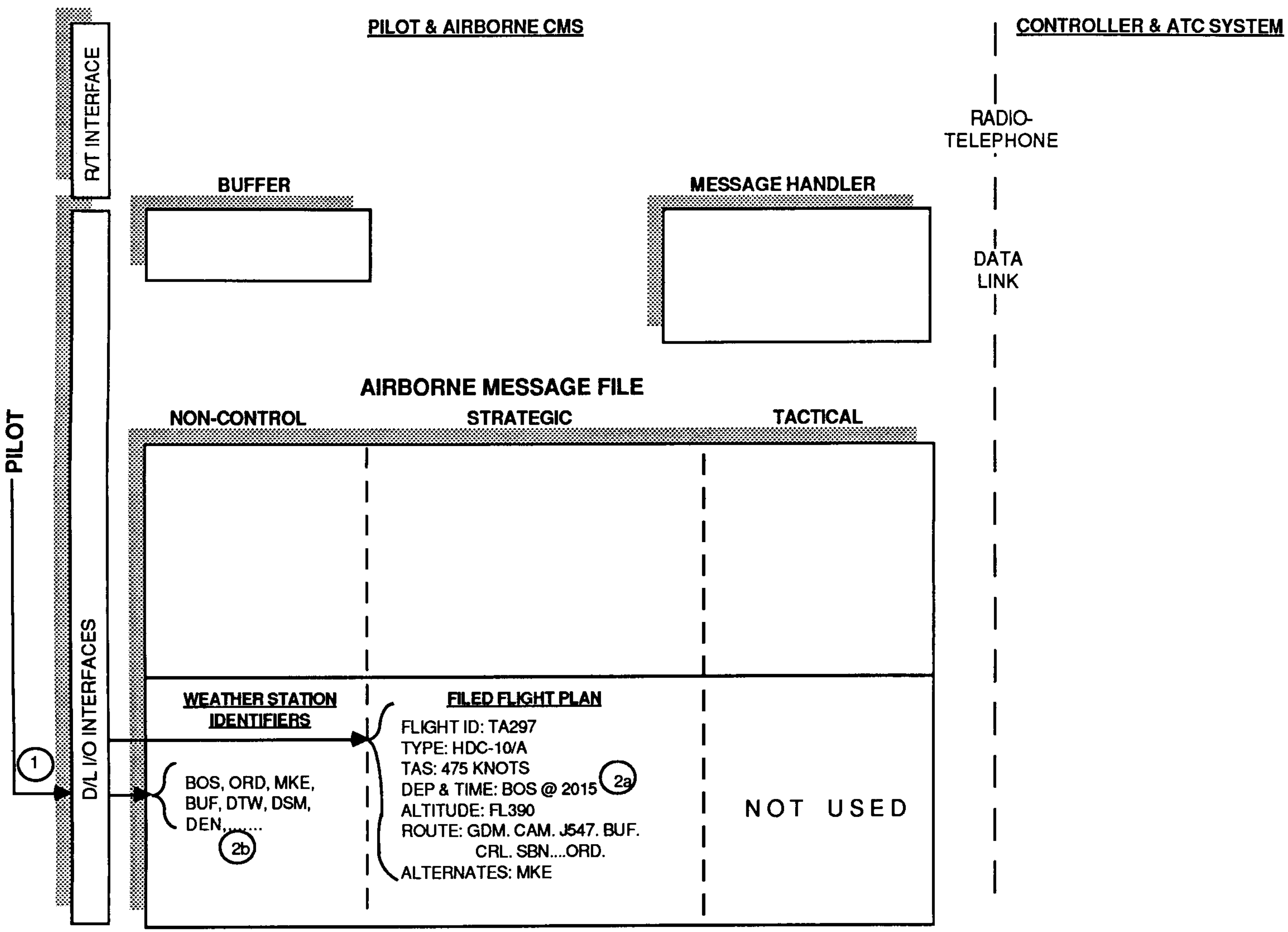

FIGURE B-1
PREFLIGHT INITIALIZATION

Time: 1945Z
Location: At BOS Gate 5

Descriptive Text for Figure B-1: This diagram outlines the contents of the static portions of the AMF after the pilot has completed the initialization process during his preflight preparation. In this example the pilot manually inserted the flight plan as filed in advance with the ATC system by direct entry with the interface, Step 1. The flight plan, 2a, contains several pieces of information which will subsequently assist the pilot in generating d/l messages. The form of the flight plan shown here is representative of the types of flight plans accepted and processed by the current ATC system. However, as more advance ATC capabilities are developed, users could be allowed to specify their proposed flight operations in more detail if they can derive a benefit in doing so. A more detailed altitude profile could be specified by the airspace user, for example, to describe planned "step-climbs" to more efficient altitudes as the aircraft burns off fuel. These advanced flight planning and ATC concepts can be applied with equal ease using this communications systems concept, but only the simpler case involving current flight plan filing capabilities is presented for brevity.

Having completed the entry of the filed flight plan into the static portion of the AMF, the pilot then enters the weather station identifiers which will be of interest to him during this flight, 2b. Prespecifying these identifiers makes the generation of weather requests easier in that the pilot need not engage in a series of keystrokes, but would rather make a selection of locations on the basis of what he had first entered during initialization. On a touch panel or line-select screen, for instance, the menu of choices could be labeled with the station identifiers which have been prestored in the AMF. If, after the flight is underway, the pilot desired to obtain weather information from a location he had not prestored in the AMF's static data area, he could still generate this request message directly on the interface without the benefit of information contained in the AMF. This may require some additional input workload on his part, but the frequency of these types of requests would probably be rare compared to requests for information from stations in which the pilot has expressed an interest. It should be noted that information contained in the filed flight plan (as entered into the AMF) may be used to help the pilot generate this list of weather station identifiers. The pilot is very likely to be interested in weather conditions and forecasts at the departure, destination, and alternate airports. Because these identifiers can be found in specific fields of the filed flight plan, the airborne system could automatically insert them in the list of weather station identifiers, to which the pilot can add others.

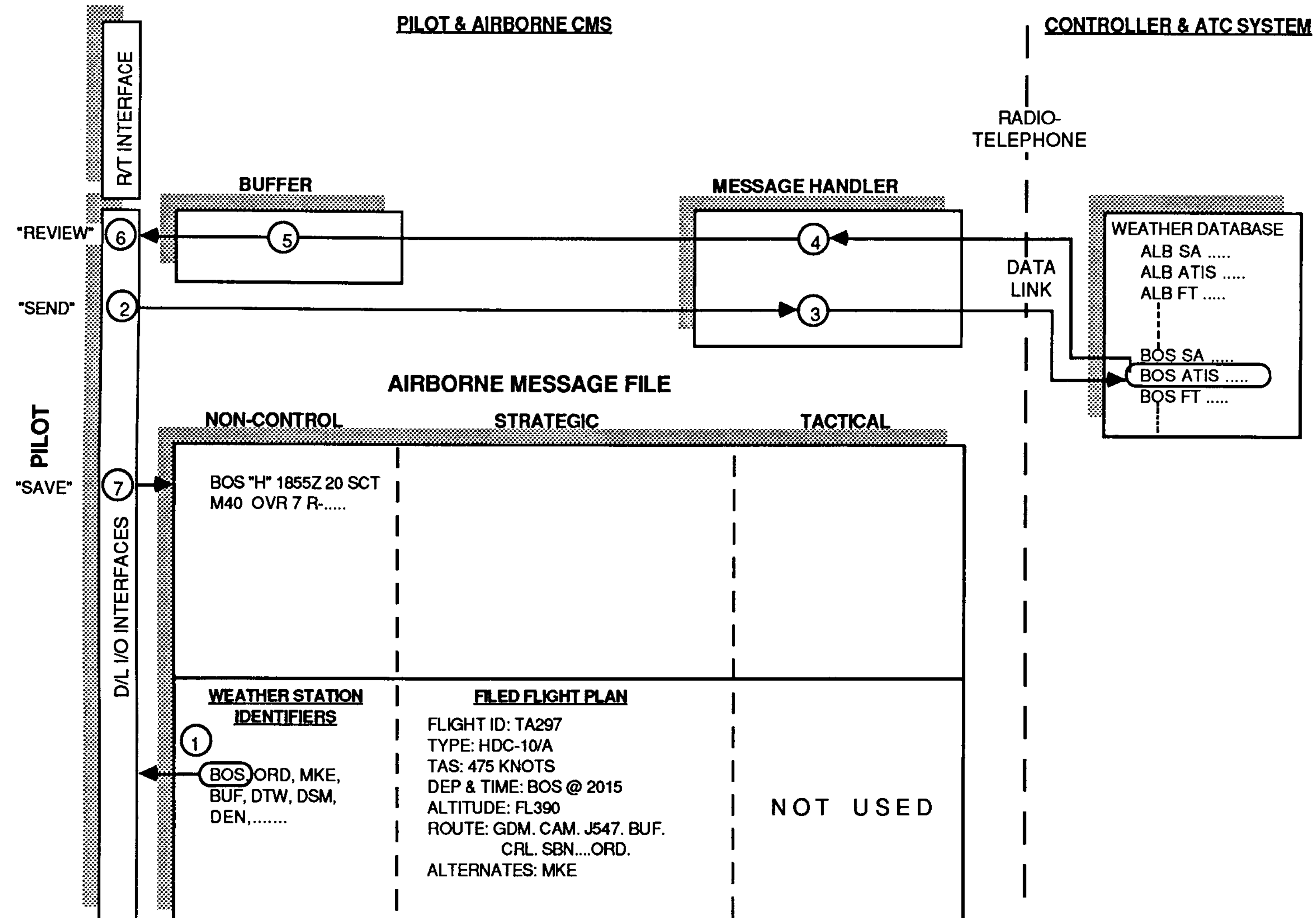

FIGURE B-2
D/L REQUEST FOR DEPARTURE ATIS

Time: 1950Z
Location: At BOS Gate 5

Descriptive Text for Figure B-2: The sequence of events and the flow of information through the airborne CMS is presented in Figure B-2 for the case where the pilot makes a request for the BOS ATIS. In Step 1 the pilot configures the interface to enable him to generate the request message; the CMS would extract the weather station identifiers from the AMF static area and present them along with a list of available weather products. The pilot would make his selections on the interface and instruct the CMS to issue a d/l request for this information in Step 2. In Step 3 the message handler performs appropriate record-keeping tasks, as well as completing all overhead chores associated with preparing and sending the request message. It is assumed that no human intervention on the "ground side" would be required for these types of non-control information exchanges; upon receipt of a request the ground system simply accesses its database to provide the desired information. When the message handler receives and decodes the response from the ground system, Step 4, it closes out this d/l transaction and forwards the message to the buffer (Step 5) where it will be retained until the pilot is ready to review it. A notice is provided to the pilot on the interface to indicate a weather message is ready for his review. When the pilot is ready to review the message, he calls the information out of the buffer onto the interface where he can analyze it (Step 6). When the pilot is finished reviewing the information, he instructs the CMS to "save" the information (Step 7), and it is automatically stored in the dynamic portion of the AMF and also made available to other parts of the airborne system. A performance management system, for instance, may use the altimeter setting, temperature, and reported winds in the ATIS message as inputs for the computation of thrust settings and takeoff speeds.

Throughout this d/l transaction, the r/t channel has remained idle as there is no need for voice communications to augment the d/l process. However, as part of the response message back to the airborne system, it may be desirable to indicate an r/t frequency which could be used, if necessary, as a backup or for additional clarification/information. The frequency would indicate the cognizant ground facility to be contacted for information related to each particular weather request.

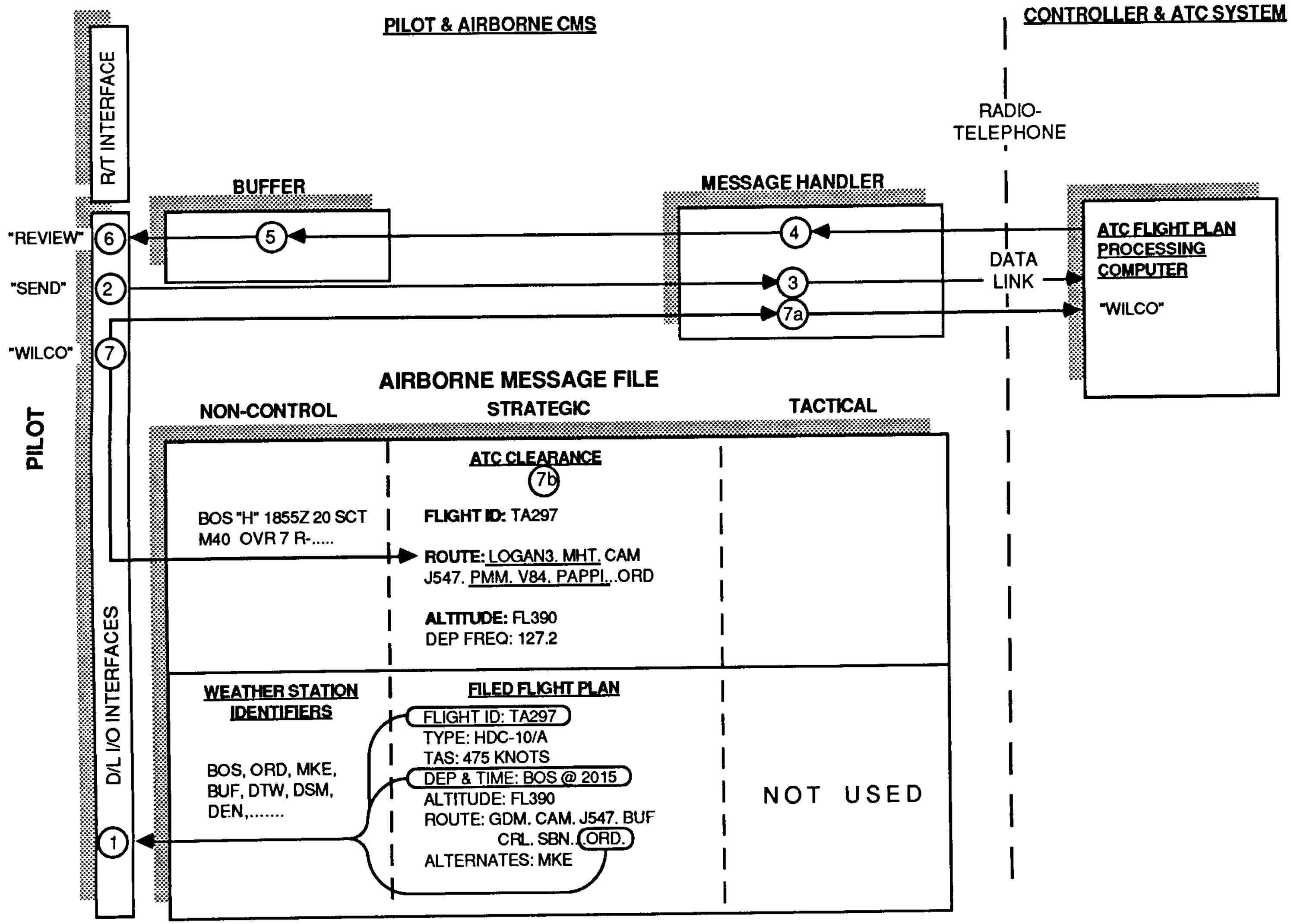

FIGURE B-3
REQUESTING/RECEIVING IFR CLEARANCE

Time: 2005Z
Location: At BOS Gate 5

Descriptive Text for Figure B-3: The next step in the scenario is for the pilot to obtain an IFR clearance on the basis of his submitted flight plan. In Step 1, the pilot uses the interface to construct a clearance request message. The CMS automatically extracts certain information from the static area of the AMF to facilitate generation of this request message. This would include, as a minimum, the aircraft's flight identifier (or r/t call sign), the departure station and estimated departure time, and the destination. After confirming the contents of the request message, the pilot would instruct the CMS to send the message requesting an IFR clearance on d/l, Step 2. In Steps 3 and 4, the message handler would tend to the overhead tasks necessary to send the d/l request message, and process the eventual reply. It is again assumed that no human intervention on the ground side of this transaction is necessary, and that the IFR clearance, itself, is automatically generated by the ground system computers. The information contained in the request for clearance is sufficient for the ground system to match the request with a flight plan which has been filed.

After receipt and decoding by the message handler, the IFR clearance is forwarded to the buffer (Step 5) and retained until the pilot is ready to review it. The pilot calls the contents of the buffer out to the interface where he can review the clearance, Step 6, when it is convenient for him to do so. In this example, even though the IFR clearance route received from the ground is slightly different from that requested in the flight plan, it is assumed that the pilot will accept the IFR clearance as received. In presenting the clearance to the pilot, the CMS may highlight or underscore those parts of the clearance which are different from what he requested in the flight plan. In this way the pilot is alerted to the areas he must watch carefully in reviewing the clearance. He indicates his acceptance decision by issuing a Wilco response, Step 7, through his pilot interface. In issuing the Wilco response, the CMS takes two separate actions. First, it sends a d/l Wilco message back to the ground system to indicate that the pilot accepts the clearance and will operate according to its provisions (7a). Second, the IFR clearance is inserted in the appropriate dynamic area of the AMF (7b). It is saved in this area for the pilot for later reference, if desired, and also for other parts of the airborne system to use (such as a navigation system using the clearance route for automatically tuning radionavigation aids, or perhaps to portray the clearance route on a moving map CRT display).

Even though, in this instance, there was no need to augment the d/l transaction with voice communications, it is desirable to indicate an r/t frequency which could be used to contact the appropriate facility should clarification be needed, or if the pilot decides to respond in a manner other than Wilco (e.g. if he indicates Unable). This r/t frequency could be provided as part of the up-linked clearance message and displayed to the pilot as he reviews the clearance on the pilot interface.

To further develop what would happen if the pilot did respond with Unable, unlike the case in the scenario, it would be necessary for the pilot and controller to use r/t to find a suitable compromise. The Unable response would cause the CMS to issue an Unable message back to the ground, indicating that an operative strategic agreement has not yet been achieved. The CMS would refrain from storing the unacceptable clearance in the AMF, and the message handler would standby for an additional clearance to be received. In other words, the Unable response causes the message handler to keep this transaction open until a revised, acceptable clearance is received and Wilcoed, or until the pilot issues a Cancel message to indicate that he no longer wants to participate as IFR traffic in the ATC system. In the meantime, the pilot and controller would engage in r/t discussions to find a suitable compromise clearance, if possible. If the two parties agree to a revised clearance, the controller and ground system should issue the revised version to the aircraft's CMS via d/l. The revised clearance would become the operative strategic agreement once the pilot reviewed the clearance and issued a Wilco response. The CMS would then enter the clearance into the dynamic storage area of the AMF. These procedures, therefore, require that the strategic agreement be "finalized" through a d/l transaction whenever d/l is the primary mode of communication between an aircraft and the ground system, even though it may be necessary to revert to r/t for an interim step in the process. This ensures that the contents of the dynamic area of the AMF are up-to-date and have completed the pilot check-and-approve process.

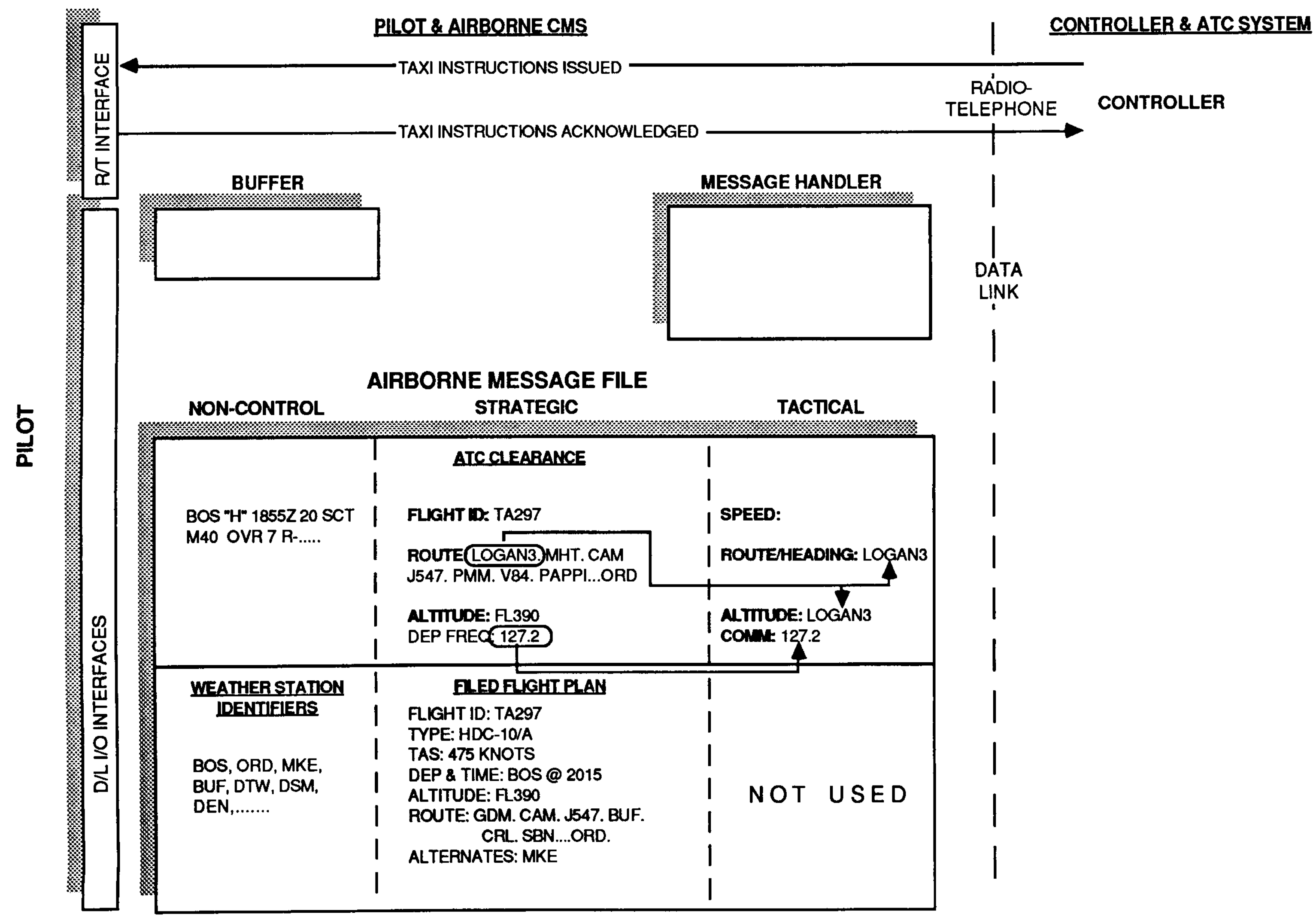

FIGURE B-4
TAXI AND TAKEOFF PREPARATIONS

Time: 2010Z
Location: At BOS, taxiing to runway 4R

Descriptive Text for Figure B-4: In this communications system concept it is assumed that taxi instructions and the general control of surface traffic will continue to be conducted on r/t. A number of factors make the issuance and acknowledgement of taxi instructions very difficult to implement on d/l. The issuance and execution of taxi instructions, for example, is extremely time critical in some instances (such as the timing of instructions to cross an active runway). As a result, r/t communications remain well suited for this application because of the crisp manner in which the instructions can be issued, acknowledged, and executed. In addition, the complex geometries of taxiways, aprons, and runways at several airports make the input/output of taxi instructions difficult to accomplish. Finally, because the ground controller is often building a queue of aircraft for the departure runway, he often issues instructions relative to other aircraft such as "follow the light-twin aircraft passing from right to left," or "hold short and give way to the DC-10, then proceed..." With such a dynamic environment, extensive improvements would be required in the surveillance and processing of ground traffic movements in order for d/l to be used effectively in this area. Therefore, as depicted in Figure B-4, all taxi-related communications would be conducted on r/t. This would not have an adverse effect on the contents of the AMF as taxi instructions are not relevant to the contents of the AMF.

Nonetheless, in preparation for takeoff the CMS could be designed to set-up the initial tactical assignments in the appropriate area of the AMF dynamic storage area. This is shown in Figure B-4 by the insertion of the term "LOGAN3" into the "Heading/Route" and "Altitude" fields of the dynamic tactical storage area, and by the insertion of the departure frequency (127.2) into the "COMM" area. These actions would be accomplished by the CMS automatically after the pilot accepts the ATC clearance. According to the taxonomy of Section 2, the LOGAN3 Standard Instrument Departure is a procedure-based tactical instruction which specifies how the flight should transition from the departure airport to the en route airspace through a series of route and climb instructions. The insertion of the term "LOGAN3" in these tactical data fields is an indication to the pilot that he should manage the initial heading and altitude on departure according to the LOGAN3 procedure. In a simple airborne system, the pilot may have to refer to a printed textual description of the LOGAN3 to determine the appropriate headings and altitudes. More sophisticated airborne systems, however, may store this description of the LOGAN3 in a navigation database, and these systems could insert the actual headings and altitudes into the AMF, thereby eliminating the need for the pilot to cross-reference a printed description. Either airborne implementation can be handled with equal ease by the concept.

The necessary company-related communications, while not shown here, could be performed at this time using procedures and message formats which are aimed at meeting company requirements. Though this scenario concentrates primarily on ATC-related communications, the CMS and airborne system could be configured to also perform data exchanges on a different data link to support company functions. Ideally, the CMS (through the Message Handler) would separately manage transactions on various links and involve the pilot only in transactions which require his attention.

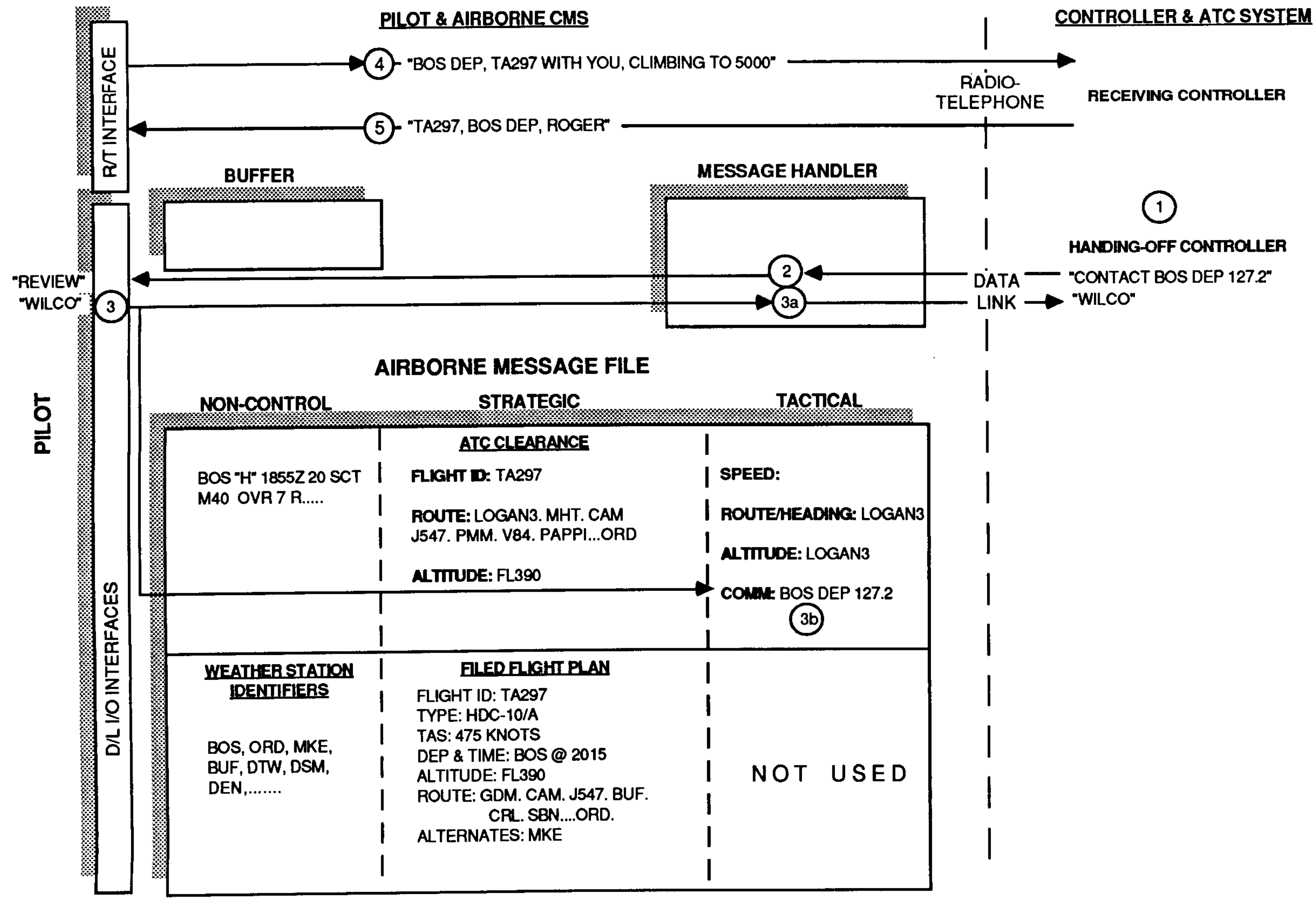

FIGURE B-5
DEPARTURE COMMUNICATIONS HAND-OFF

Time: 2015Z
Location: Shortly after lift-off from BOS runway 4R

Descriptive Text for Figure B-5: This figure illustrates the initial steps taken to establish d/l as the primary communications mode between the airborne aircraft and the ATC system after takeoff clearance. As mentioned for the case of taxi instructions, the issuance, acknowledgement, and execution of takeoff instructions (or position-and-hold instructions) can be extremely time critical: even more so than for tactical instructions issued to aircraft already in flight. Therefore, r/t remains the primary communications mode for the issuance of the takeoff clearance. For clarity, these r/t exchanges are not presented in Figure B-5, but would be similar to the exchange process illustrated for taxi. Although it has been considered that a simultaneous d/l message could be used as a "confirmation" of the r/t takeoff clearance, this may give rise to more problems than benefits. The use of one mode (d/l or r/t) to serve as a confirmation of messages received on the other makes receipt of two forms of the same message necessary for it to become an operative agreement. However, because for the foreseeable future d/l coverage may not exist throughout all navigable airspace, pilot confusion is likely as he waits for d/l confirmations that he is not going to receive.

Once the aircraft has taken off, the local controller "hands off" the flight to the radar controller by issuing a d/l tactical instruction to the aircraft to change r/t frequencies. The issuance of this d/l message causes the ground system to signal the receiving controller that a new flight is about to check-in on his r/t frequency. The local controller would first send a hand-off message to the aircraft, which would include the title of the next facility and the appropriate r/t frequency, as shown by Step 1. This frequency would, in many cases, be the same frequency noted in the departure frequency field of the IFR clearance; but it need not be. The primary reason for specifying a departure frequency in the IFR clearance is to provide an r/t contact in the event d/l communications cannot be established after the aircraft is airborne. However, if the d/l hand-off message makes it through to the pilot, it could specify a different frequency if necessary.

Once the airborne message handler receives and decodes the frequency change instruction (Step 2), it bypasses the buffer and forwards the information directly to the pilot interface for his review and action. Pilot acceptance of the instruction is indicated by his Wilco in response to this message. This action causes the CMS to issue a Wilco message back to the ground, Step 3a, which closes out this d/l transaction. It also causes the information to be entered into the appropriate dynamic field in the AMF, as shown by Step 3b. Once entered into the AMF, other parts of the airborne system may reference it. An example of this might be an airborne system which would tune communications radios automatically and eliminate the need for the pilot to perform this task manually.

Although this d/l transaction has been completed at this point, and d/l communications have now been established as the primary mode between this aircraft and the ground, it would still be recommended procedure for the pilot to perform a standard r/t "check-in" on the new frequency (Steps 4 and 5). This would ensure that the r/t channel is operative and that the pilot has established both r/t and d/l communications with the correct controller.

It should be noted in this and subsequent figures that the examples of data link messages are intended only to show the information exchanged, rather than the format which could or should be used. Many different symbols, shorthand techniques, and encoding schemes could be used to increase d/l information throughput while still keeping the information meaningful to the human and supporting automation.

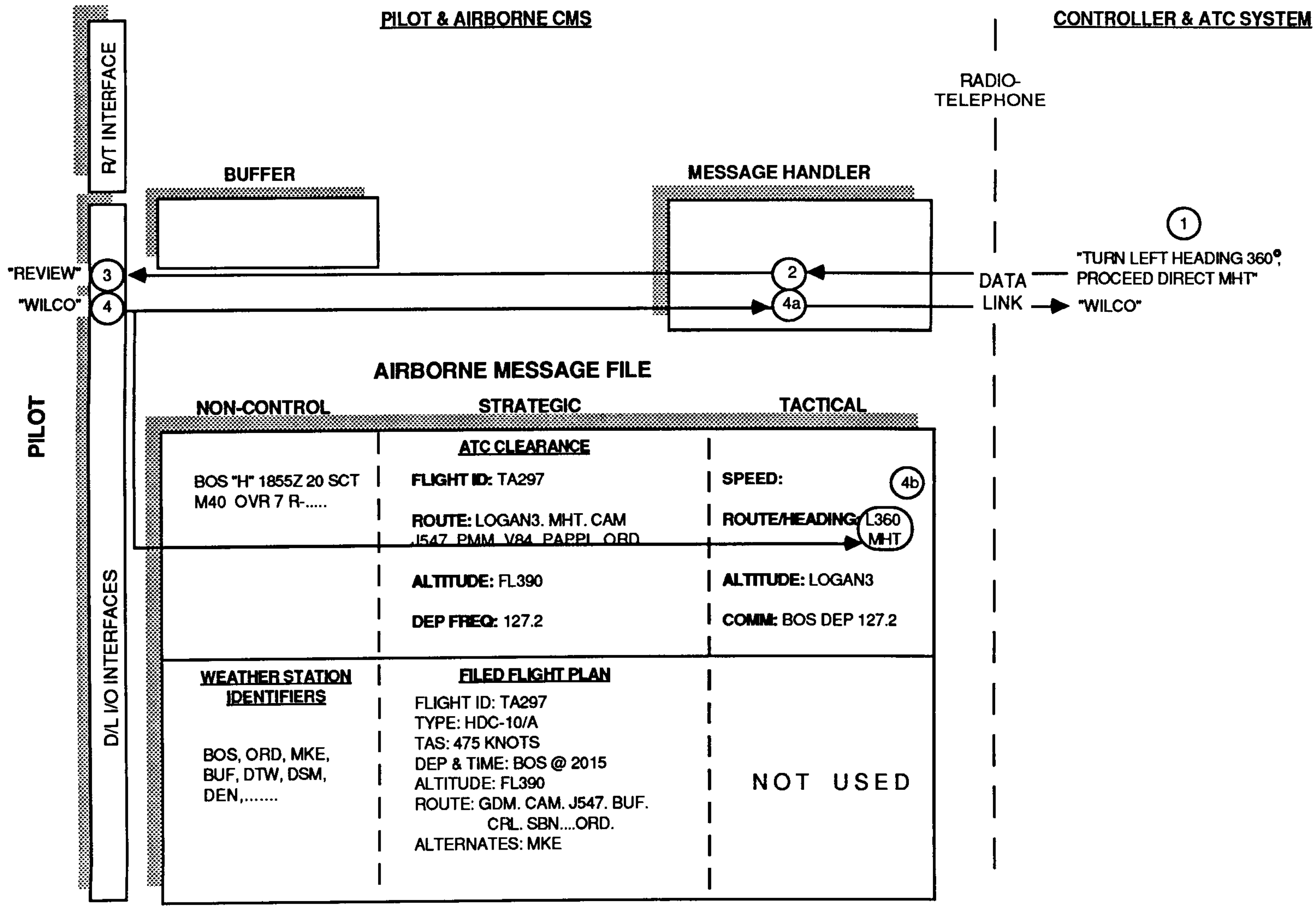

FIGURE B-6
RADAR VECTOR INSTRUCTION

Time: 2017Z
Location: On initial climb from BOS terminal area

Descriptive Text for Figure B-6: Procedurally, TA297 is expected to follow the LOGAN3 departure until the controller provides the necessary heading and altitude instructions to transition the aircraft into the en route environment. The d/l transmission of the first such instruction is illustrated in Figure B-6, in which the controller provides an initial heading to the Manchester (MHT) VOR. As for the communications handoff, the process is initiated when the controller instructs the ground system to send the desired d/l message (Step 1). The message handler receives and decodes the message (Step 2), and forwards it directly to the pilot for his review (Step 3). The pilot's Wilco response causes the CMS to, again, take two separate actions. It first issues a Wilco message back to the ground system which closes out this particular d/l transaction (4a), and then it enters the new tactical instruction into the appropriate field in the AMF's dynamic storage area (4b). Because this new tactical agreement supercedes the previous one, the previous "Heading/Route" entry is erased and replaced with the Wilcoed instruction, namely "L 360 MHT." However, other tactical assignments, such as altitude, are not affected by this particular transaction and are, therefore, maintained in their present status in the AMF. It should be noted that if no tactical assignment is made for a flight parameter (such as speed), that determination is left to the pilot's discretion.

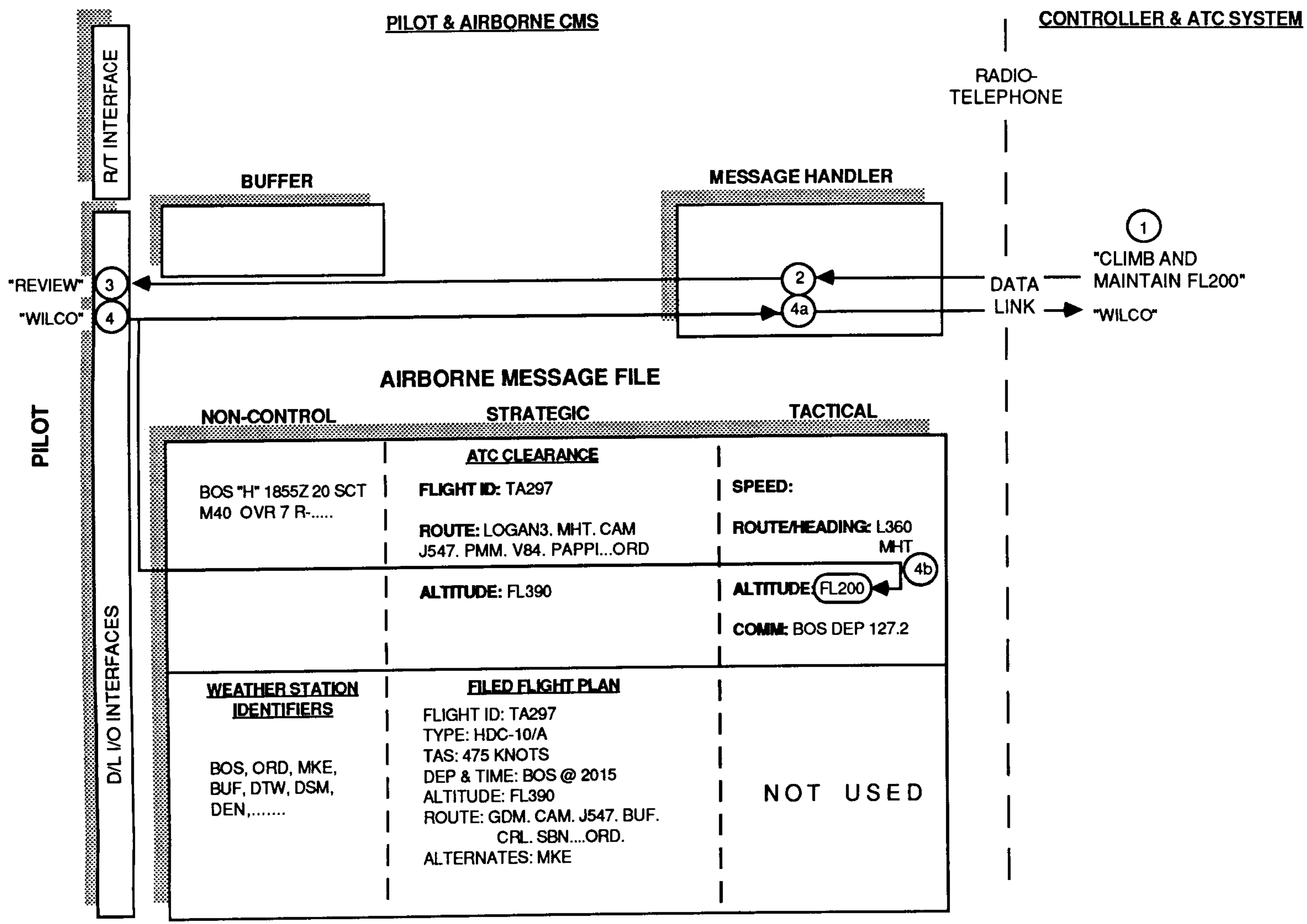

FIGURE B-7
TACTICAL MESSAGE TO CHANGE ALTITUDE

Time: 2018Z
Location: On initial climb from BOS terminal area

Descriptive Text for Figure B-7: In this figure, the tactical instruction for the aircraft to climb and maintain a new altitude is depicted. Prior to this d/l transaction and pilot acceptance of the new altitude, the pilot was limited in his climb to 5000 feet as contained in the altitude restriction of the LOGAN3 departure. The process of conducting this transaction is identical to that used in the previous two figures. Once the pilot makes the Wilco response and the CMS has updated the list of tactical assignments with the new altitude, other parts of the airborne system may use this information depending on the airborne system architecture. The new altitude value could be inserted directly into an altitude alert function, and depending on how the pilot has elected to program the automatic flight control system, may also be used by the autopilot.

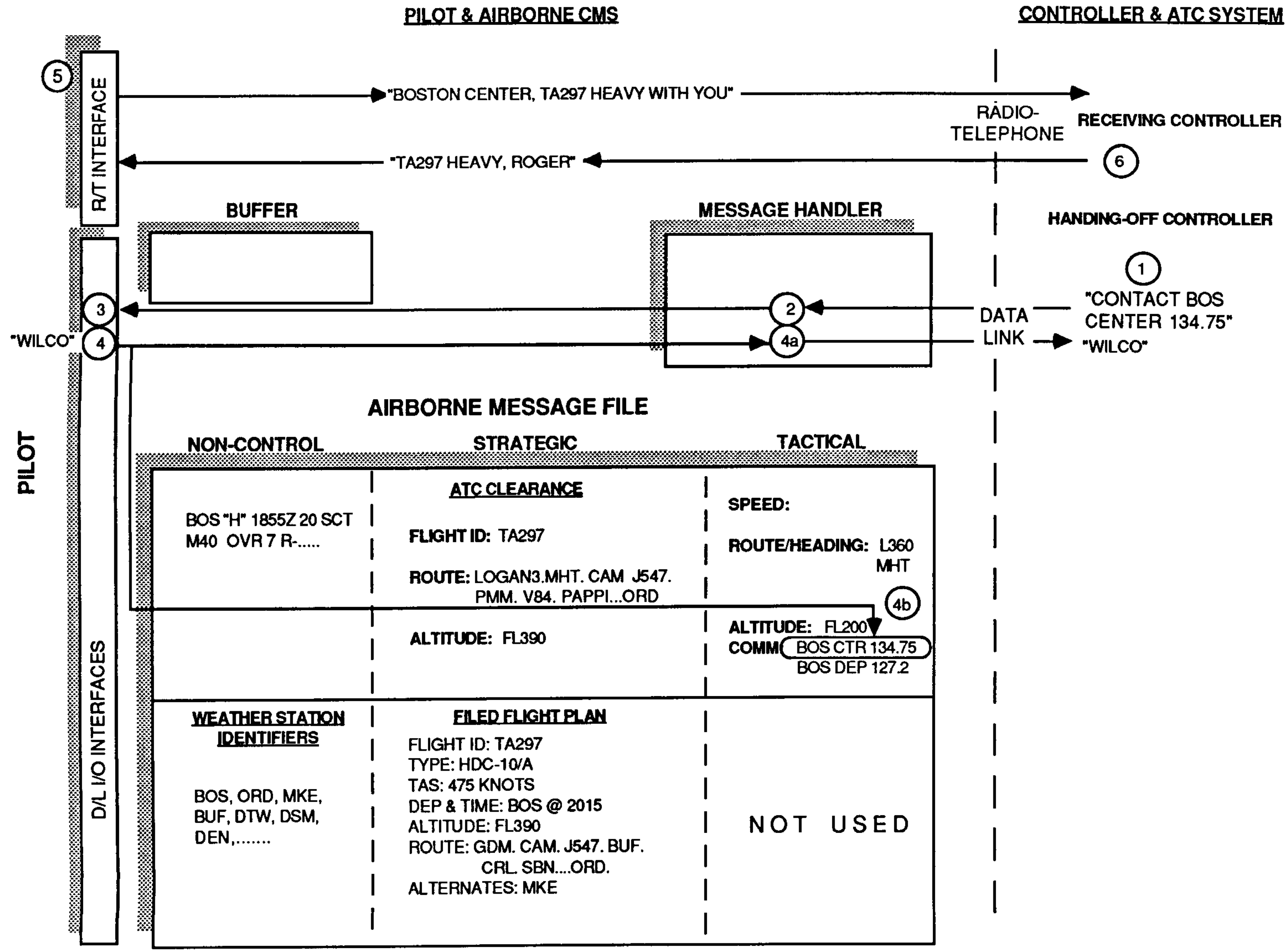

FIGURE B-8
COMMUNICATIONS HANDOFF

Time: 2018Z
Location: On initial climb from BOS terminal area

Descriptive Text for Figure B-8: The same basic flow of information and sequence of events takes place for this communications handoff as for that described in Figure B-5. However, rather than erasing the old communications frequency when the new one is entered into the AMF, the CMS retains a record of the old frequency. This provides a back-up frequency the pilot can use if he is unable to establish r/t communications on the new frequency.

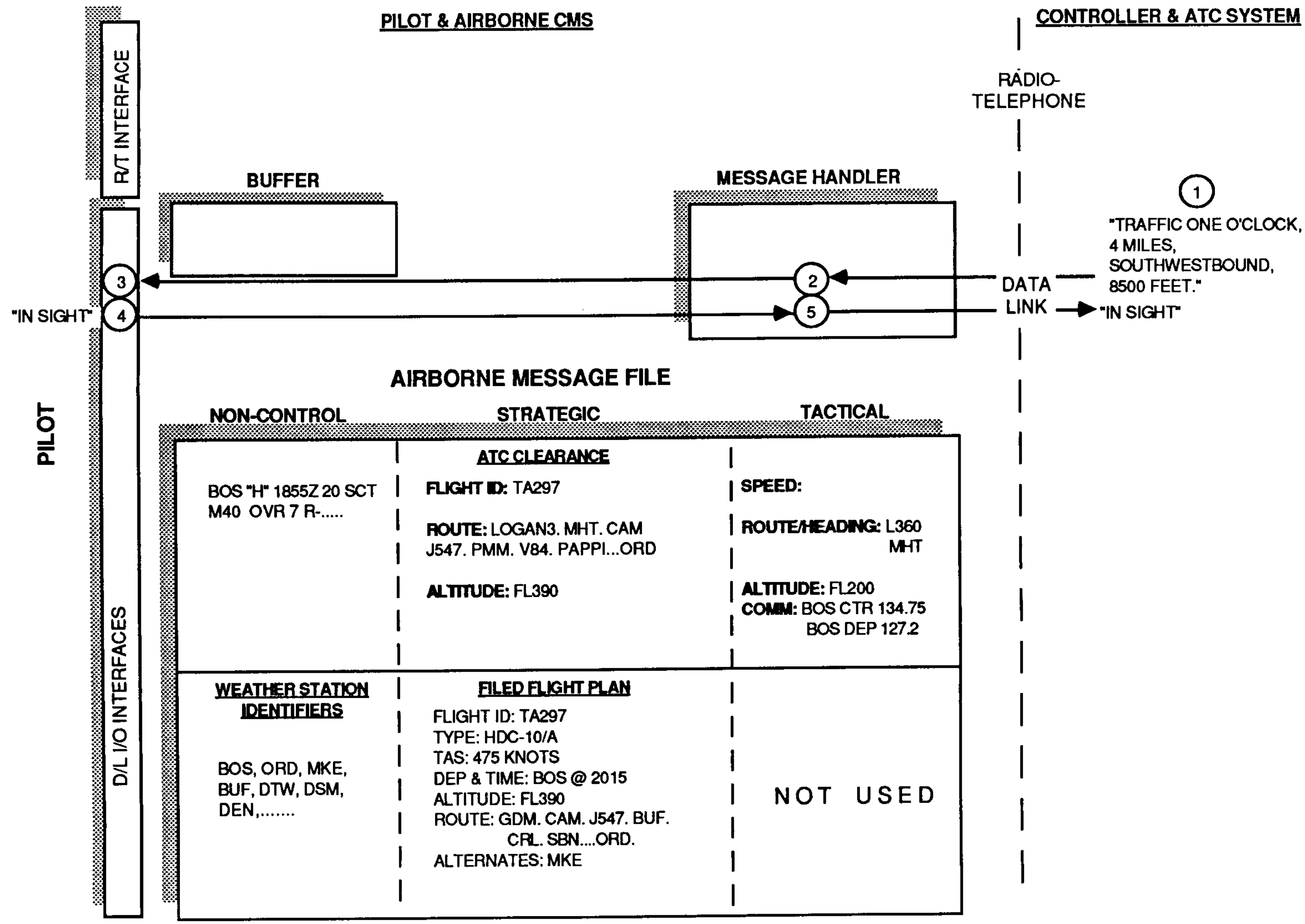

FIGURE B-9
TRAFFIC ADVISORY

Time: 2020Z
Location: Approximately 12 miles south of MHT VOR

Descriptive Text for Figure B-9: This figure illustrates the flow of information used for an urgent advisory such as that associated with proximate traffic. In Step 1 it is assumed that the ground system either automatically constructs the message, or provides the controller with suitable aids to point out the traffic. After passing through the message handler and proceeding to the pilot interface, the pilot may respond that the traffic is "IN SIGHT," or that there is no visual contact (i.e. "NO CONTACT"). Because there is no value in saving these temporary advisories, the pilot's response is simply transmitted back to the ground and the CMS takes no further action.

If the pilot responds to the advisory with "IN SIGHT," the controller would suspend issuing further advisories on that particular traffic target. If the pilot responds with "NO CONTACT," the controller would continue issuing traffic advisories at appropriate intervals until the pilot responds with "IN SIGHT," or the traffic is no longer a factor (in which case the controller would issue a message indicating the traffic is no longer a factor).

It should be noted that display of such traffic advisories in the cockpit could be performed graphically or textually. The basic information content is the same in either case, and the CMS would route the advisory to the appropriate interface depending on how the aircraft is equipped. Therefore, the ground system could issue these traffic advisory messages using a single standard format and still satisfy varying display requirements in the cockpit. In addition, the CMS would also perform the requisite record-keeping functions to keep track of multiple traffic advisories until the ultimate disposition of each one.

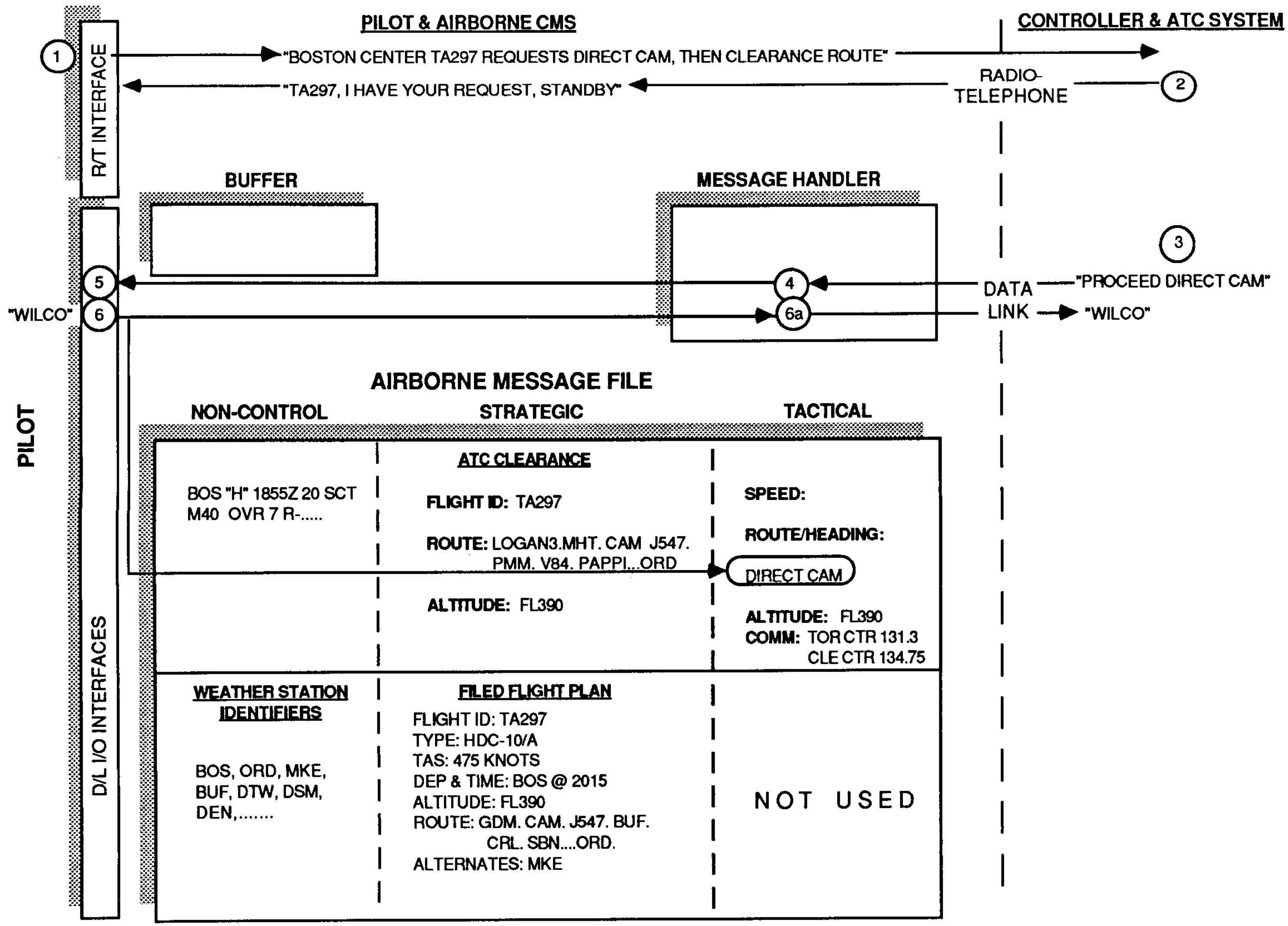

FIGURE B-10
AIR-INITIATED REQUEST FOR SIMPLE CHANGE IN ROUTE

Time: 2021Z
Location: Approximately 10 miles south of MHT VOR

Descriptive Text for Figure B-10: As illustrated in the r/t scenario of Appendix A, at this point in the flight the pilot desires to cut a dogleg corner off his route by skipping MHT VOR and proceeding directly to CAM VOR. Just prior to issuing a request to change his route, the contents of the pertinent areas of the AMF were as follows:

Strategic route assignment: LOGAN3.MHT.CAM.J547.PMM.V84.PAPPI...ORD

Tactical heading/route assignment: L 360° DIRECT MHT
(a left turn to a heading of 360° and then direct to MHT VOR).

In the strictest sense, the proposed modification (to skip MHT and proceed direct to CAM) would require amendments to both the strategic route assignment and the tactical heading/route assignment as both of these entities specify MHT VOR as part of the routing. However, in view of the fact that the proposed modification represents a very slight change to the strategic agreement on the current leg of the flight, this change could be accommodated through a single ATC tactical instruction. (A more complicated route amendment is illustrated in the next section for the ORD-DEN segment).

The pilot would initiate an exchange to modify his route by issuing an r/t message to state his preference, as shown in Step 1. The controller would provide his initial response using r/t to close the r/t loop and to let the pilot know that the request was received and understood (Step 2). Two potential controller r/t responses at this point would be "UNABLE" (meaning the controller cannot accommodate the pilot's request), and "STANDBY" (meaning the controller has received the request and is working on it). In the first case, the exchange process associated with this request is opened and closed using only r/t: there is no need to conduct d/l exchanges associated with such denied requests.

The second case, however, leads to a series of d/l exchanges as illustrated in Figure B-10. The controller would first command the ground system to issue a tactical d/l message to the pilot instructing him to change the route as he had requested, as shown in Step 3. After the message is processed by the airborne message handler (Step 4), it is forwarded directly to the interface for the pilot's review and concurrence (Step 5). The pilot would indicate his concurrence by issuing a d/l WILCO response back to the ground (Step 6). The CMS would then transmit the d/l WILCO message as shown by Step 6a, and would also revise the tactical route/heading field of the AMF (Step 6b).

It should be noted that even though the air-initiated revision request is started on r/t, actual clearance revisions are always issued on d/l whenever d/l has been established as the primary means of message exchange between the ground and the air. This is to ensure that the humans and machines are maintained in common information update loops. Otherwise, agreements made between the pilot and controller may never reach the AMF or the appropriate parts of ground system. Therefore, in this case, r/t may be considered only as a means of starting the process, but the proposed new tactical agreement does not become the operative agreement until he pilot issues the d/l WILCO message back to the ground.

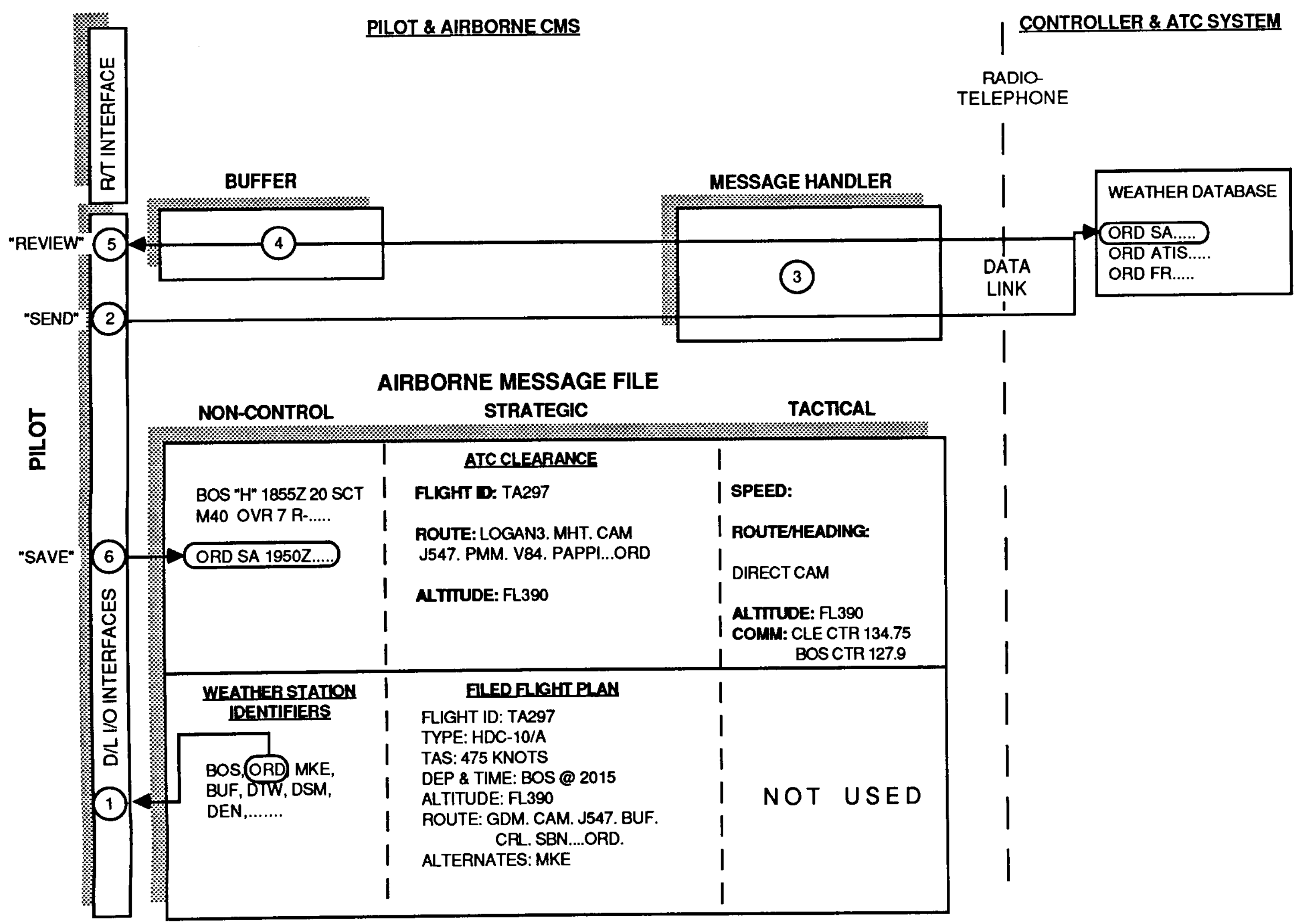

FIGURE B-11
REQUEST FOR DESTINATION WEATHER

Time: 2113Z
Location: Approximately 100 miles east of BUF VOR, on J547.

Descriptive Text for Figure B-11: This figure illustrates how the pilot might issue a request for the latest weather at the destination airport. In the interval since the transaction describe in the previous figure, the following exchanges (which parallel those in the r/t scenario) have taken place.

Time	Exchange
2028Z	TA297 given d/l tactical messages to climb to FL390.
2030Z	TA297 issues an "off" report to the company.
2037Z	Controller instructs TA297 to contact another sector on 135.25 (Note: The reliability of digital data exchanges should eliminate the occurrences of erroneously copied frequencies such as that illustrated in the r/t scenario for this exchange).
2055Z	Controller hands off TA297 to another sector on 127.9.
2108Z	Controller hands off TA297 to next facility, Cleveland (CLE) Center, on 134.75.

The contents of the AMF in Figure B-11 reflect the latest tactical and strategic assignments resulting from these intervening exchanges.

To issue the request for destination weather, the pilot would first make a selection of the weather location (ORD) and the information desired (in this case an hourly surface observation) using the pilot interface as shown by Step 1. Steps 2, 3, 4, and 5 trace the routine sequence of events in which the pilot and CMS would be involved in sending the request and reviewing the ultimate reply from the ground. (As in the case of requesting ATIS information (Figure B-2), it is assumed that no human intervention is required on the ground and that the automation simply accesses the weather database to provide the response). After the pilot reviews the information he may "SAVE" the data in the AMF for later retrival/referral (Step 6).

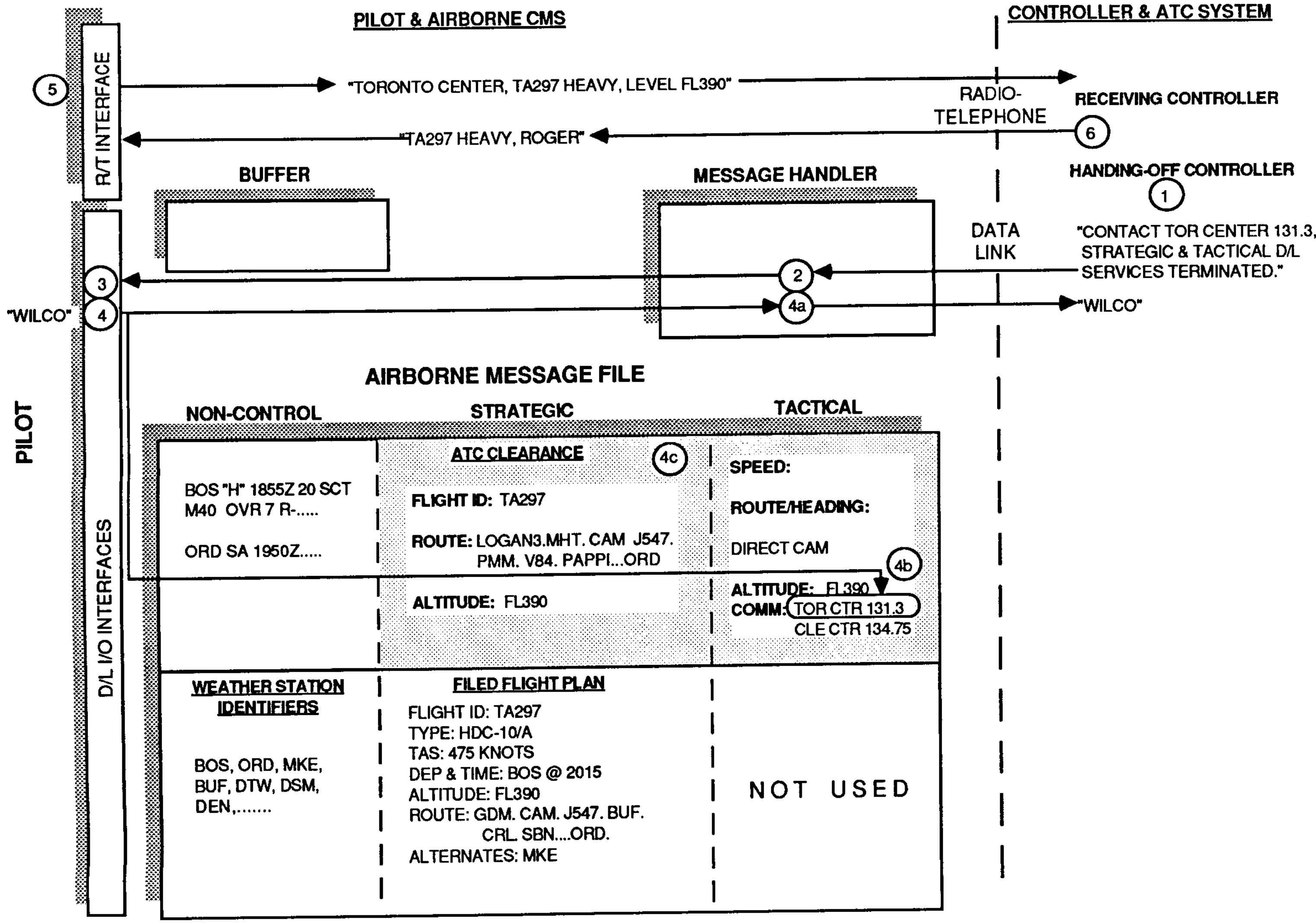

FIGURE B-12
PLANNED TERMINATION OF D/L SERVICES

Time: 2128Z
Location: Approximately 80 miles west of BUF VOR on J547

Descriptive Text for Figure B-12: Just prior to the exchanges depicted in Figure B-12, TA297 had issued an r/t request to modify the current strategic agreement to the one it had originally submitted in its IFR flight plan. However, the ATC system was not able to honor this request and the controller indicated this to the pilot using r/t. As a result, no d/l exchanges were necessary and the contents of the AMF remained unchanged from the previous figure.

Figure B-12 describes the r/t and d/l exchanges which might occur just prior to entering Canadian airspace under the jurisdiction of Toronto Center. In order to illustrate how the airborne and ground systems make a planned transition from d/l to r/t as the primary mode of communication, it will be assumed that Toronto Center is not capable of conducting d.l exchange of either tactical or strategic messages. This is known in advance by the handing-off controller and the Cleveland Center system, and the d/l hand-off message includes the notation that d/l services will be terminated when closure is reached for this last d/l exchange (Step 1). The message is decoded by the message handler and forwarded to the pilot for his review and response (Steps 2 and 3). The CMS takes three separate actions when the pilot issues a WILCO response. First, the message handler transmits the WILCO message back to the ground system which indicates the pilot will comply with the instruction and which also closes out this d/l transaction (4a). Second, the CMS inserts the new frequency and facility name in the appropriate portion of the AMF (4b). Finally, the affected fields in the AMF are "flagged" to indicate that information in these fields may no longer be appropriate or up-to-date. Because all subsequent exchanges involving these message types will be conducted on r/t, the AMF will not be in-the-loop for automatic updating. As a result, the total airborne system design should incorporate appropriate safeguards to restrict or limit the use of flagged AMF data. As an example, when d/l is established as the primary mode the pilot may program the autopilot to fly the heading and altitude as contained in the AMF tactical data area. However, when r/t is the primary mode, and d/l exchanges are terminated, the airborne system should inhibit or restrict such use of flagged data because they may no longer be applicable.

In Steps 5 and 6, the pilot and the receiving controller complete the standard r/t check-in and acknowledgement. At this point r/t has been established as the primary and only means of air-ground communication, and standard r/t procedures are employed in much the same way they are used in today's ATC system.

Figure B-12 illustrates the case where a planned termination of d/l services coincides with a handoff to another facility, but similar procedures could also be used in the case of planned d/l terminations which do not accompany a facility change, and for unplanned terminations. In the first case, for example, the aircraft may be scheduled to proceed into areas where d/l coverage is not provided even though there is no change in the cognizant ATC facility. In this case the controller would simply issue a d/l message indicating that d/l services are terminated. The pilot and CMS would take the appropriate steps to close out the d/l transaction and flag the affected areas of the AMF, and the pilot and controller would revert to standard r/t procedures/

An unplanned termination or interruption to d/l services may result from the failure of any air or ground d/l component. The airborne system may detect a failed state of the d/l system by the inability to conduct routine d/l transactions. In this case the airborne system would issue a notice to the pilot and flag the affected areas of the AMF. The pilot would then indicate the d/l failure to the controller using r/t, and the pilot and controller would establish r/t as the primary mode. Depending on the number of d/l exchanges which are made in a nominal time-frame, it may be desirable for the airborne and ground systems to periodically and automatically query their counterparts to determine the operational status of the link. This would ensure that failures are detected in a timely fashion, especially in those cases where routine exchanges are infrequent.

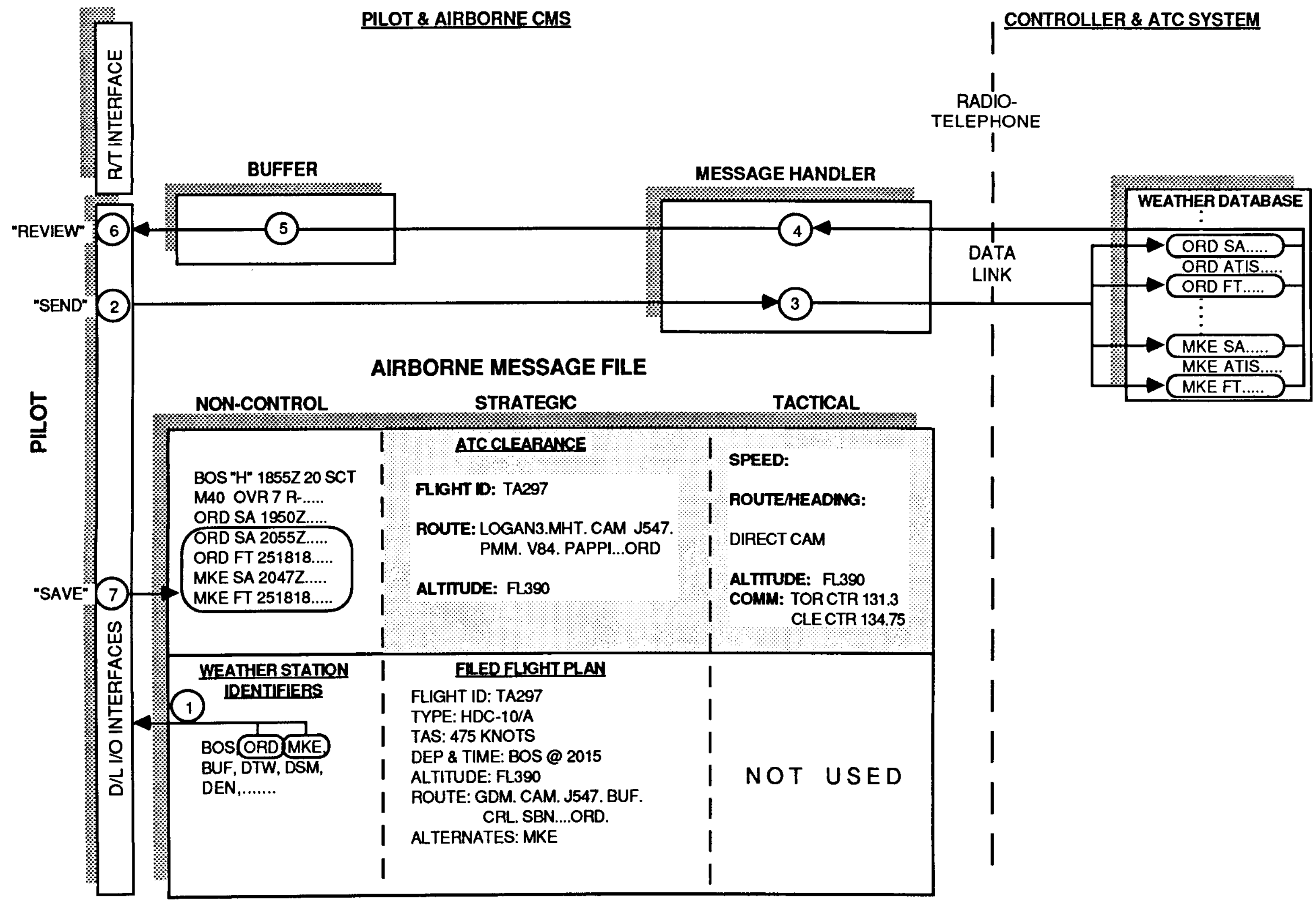

FIGURE B-13
D/L WEATHER REQUEST

Time: 2137Z
Location: Over the London, Ontario (YXU) VOR.

Descriptive Text for Figure B-13: As TA297 crosses the YXU VOR, it issues a d/l request for more up-to-date weather information on ORD and MKE. In a manner similar to that described for Figure B-11, the pilot selects the weather station identifiers of interest and desired weather products and then instructs the CMS to issue request messages for the information. In this instance where the pilot has multiple requests, the CMS automatically separates or combines the requests (as necessary for transmission on the appropriate link), and submits the appropriate messages soliciting the information. The CMS would also assemble the d/l responses from the ground and format the data for eventual presentation to the pilot. After the pilot reviews and saves the information, the CMS stores it in the non-control information area of the AMF. Depending on user requirements and preferences, the CMS could keep a running file of entries in the non-control information area where each new entry is tagged and maintained alongside earlier entries. This would enable the pilot to detect trends in weather conditions by observing how conditions are changing from a series of weather reports.

It should be noted in this scenario that weather requests are still being serviced by d/l even though strategic and tactical d/l services have been suspended. This situation may arise when the d/l is physically capable of handling information exchanges such as those associated with weather data, but end-to-end connectivity has not been established between the pilot and controller for d/l to be used for strategic or tactical exchanges. It could also arise if different links are used for the various types of information exchanges.

It should also be noted that the need to monitor the ability of the link to conduct non-control information exchanges (and flag the affected data when a failure is detected) is not as critical as for strategic or tactical messages. Non-control messages are somewhat "dated" even as they are received in the cockpit, and are not exceedingly time-critical. In addition, the information contained in these messages is not likely to be applied in very critical airborne functions, as would be the case when tactical messages eventually program the autopilot. Therefore a failure of the link to support non-control information exchanges would have only a slight impact on the operation of the aircraft.

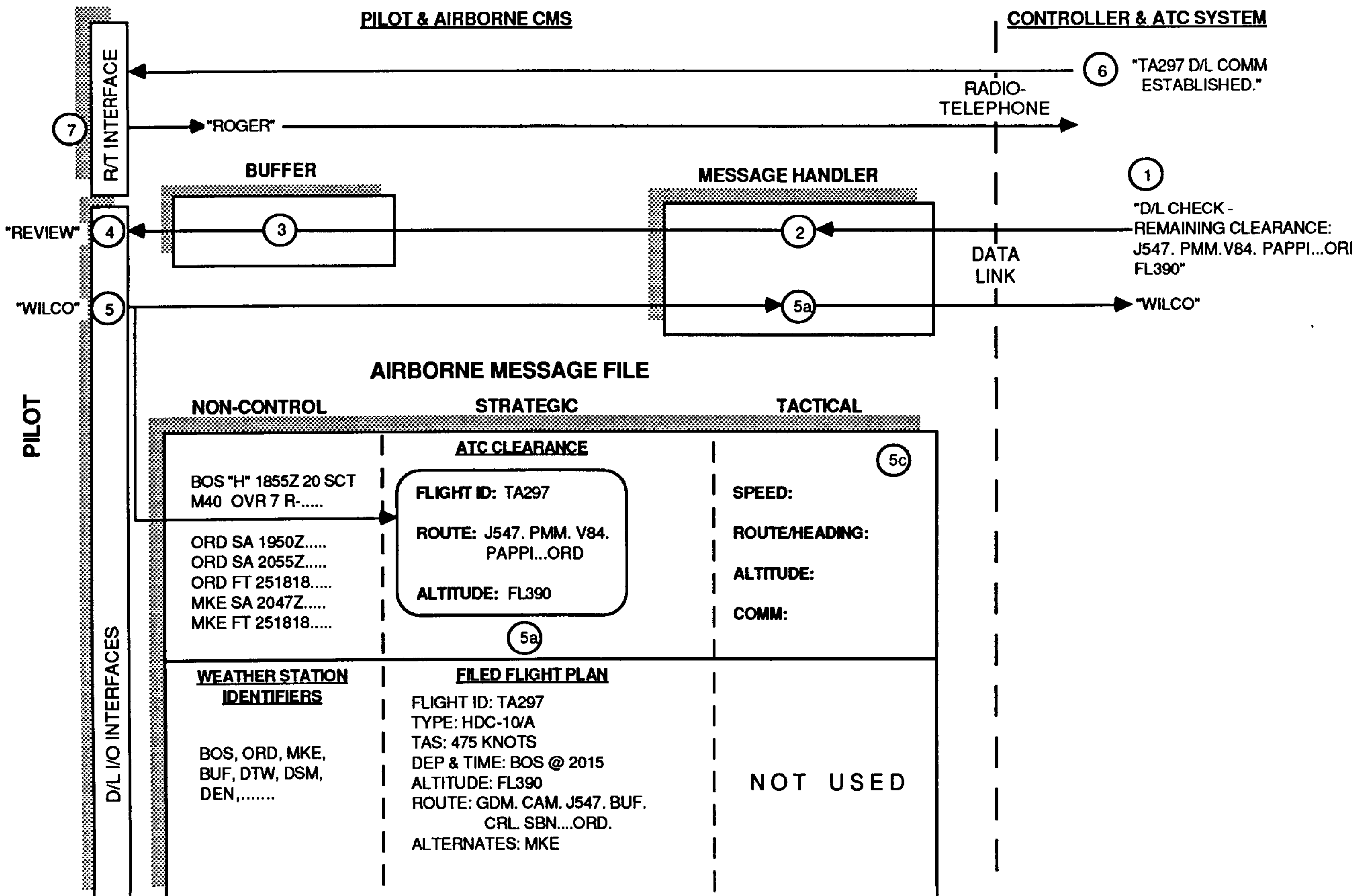

FIGURE B-14
REESTABLISHING D/L COMMUNICATIONS

Time: 2143Z
Location: Approximately 40 miles east of Peck VOR (ECK) on J547.

Descriptive Text for Figure B-14: This figure illustrates the events which would take place for the pilot and controller to reestablish d/l as the primary mode of communications between the air and ground. It is assumed that TA297 has been handed off to Cleveland Center again from the non-d/l Toronto Center: the pilot has performed a standard r/t sign-off from the Toronto Center and a standard r/t check-in on the new Cleveland frequency. At this point the receiving Cleveland controller instructs the ground system to query the aircraft via d/l as a means to check d/l operations (Step 1). As part of this check the ground system uplinks the remaining strategic clearance for confirmation by the pilot. This provides an opportunity for the pilot to double-check his clearance (which may have been amended in the interim when d/l exchanges were suspended). The message is decoded by the message handler and forwarded to the buffer (Steps 2 and 3) until it is called out for review by the pilot (Step 4). If the pilot agrees with the remaining strategic agreement as received in the uplink message, he issues a WILCO response back to the ground which causes the CMS to complete three different actions. First, in Step 5a, the d/l WILCO message is sent down to the ground thus completing the end-to-end d/l continuity check. Then in Step 5b the contents of the strategic area of the AMF are revised to reflect the latest strategic agreement. Finally, in Step 5c, the list of obsolete tactical assignments is cleared and the flags are removed from the affected data fields thereby enabling the pilot to again configure his airborne system to reference the contents of the AMF for programming and operating parameters. (If the controller wishes to issue new tactical instructions he can do so after he has received the pilot's WILCO message confirming d/l operation). As a final step in reestablishing d/l as the primary mode, the controller issues an r/t message indicating that d/l communications have been resumed.

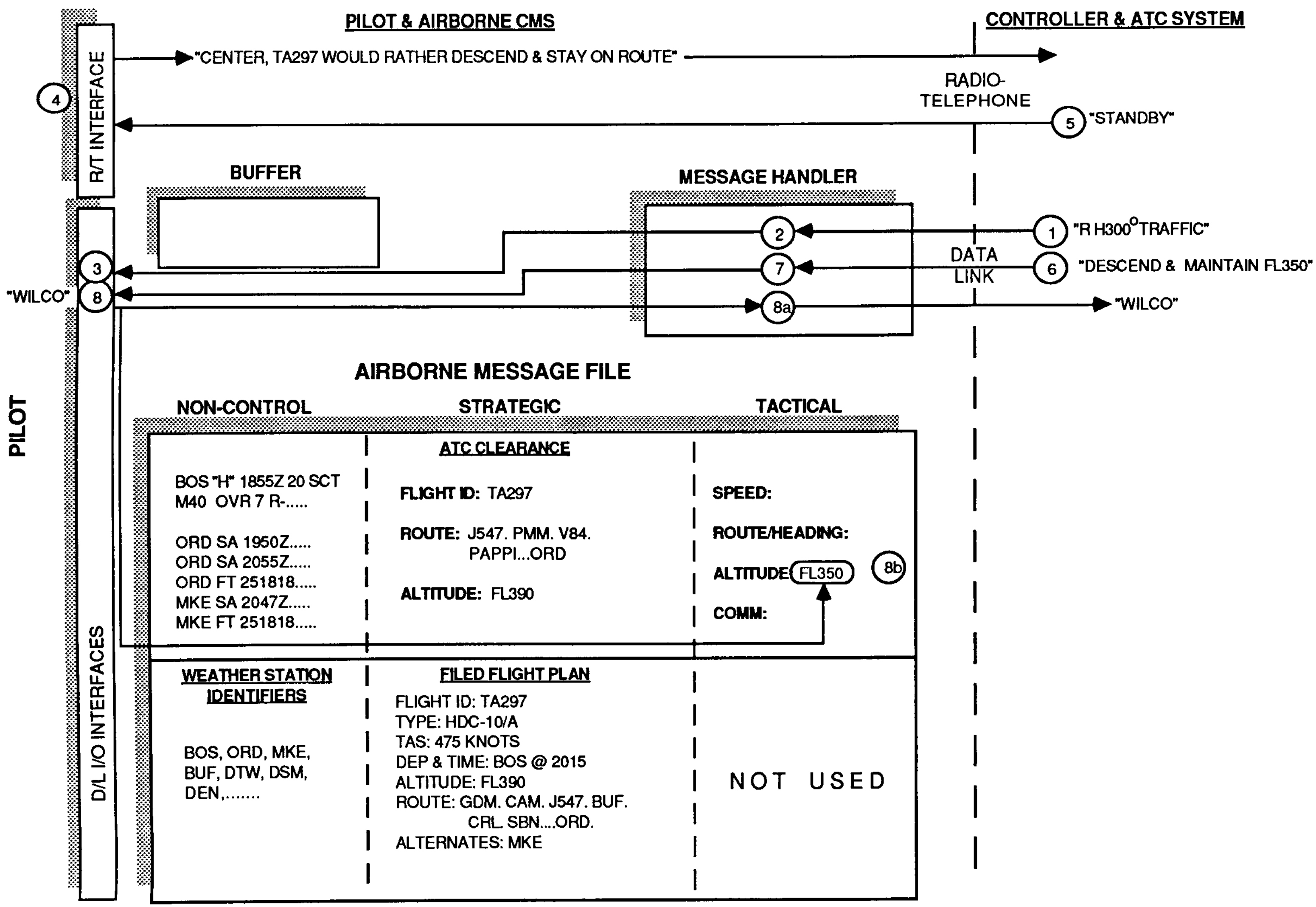

FIGURE B-15
PILOT / ATC RESOLUTION OF TRAFFIC CONFLICT

Time: 2155Z
Location: Just west of Flint VOR (FNT).

Descriptive Text for Figure B-15: This figure illustrates how the pilot and controller might negotiate a suitable course of action to resolve a traffic conflict. It is first assumed that the ground system issues an "off-route" d/l vector (R H300° TRAFFIC) as a first attempt to resolve the problem (as shown by Step 1). After processing by the message handler (Step 2) it is forwarded to the pilot interface for pilot review (Step 3). At this point it is assumed that the pilot does not wish to comply with this instruction if a more desirable alternative can be found. Therefore, rather than issuing a WILCO message back to the ground, the pilot contacts the controller via r/t and proposes an alternative (Step 4). The controller would acknowledge receipt of the proposal via r/t (Step 5). If the controller cannot accommodate the proposed alternative, he could indicate so, in which case the pilot would have to respond with a d/l WILCO message for the pending d/l transaction. However, in this example the controller can accommodate the proposed alternative, and to finalize this agreement the controller issues a revised tactical message to the aircraft instructing it to descend as requested in the pilot's proposal (Step 6). The message handler would process this message as a revision to an earlier d/l message which is still pending (Step 7). The message would be forwarded to the interface for the pilot's WILCO response (Step 8), and the WILCO message would be transmitted back to the ground (8a) and the appropriate fields of the AMF would be updated.

The principle applied in this instance where r/t communications are used to supplement d/l transactions is that agreements should be concluded between the air and ground system via d/l whenever d/l is the primary mode of communication. This provides flexibility for the pilot and controller to discuss optional ways to address various situations, but assures that appropriate elements of the air and ground system are in-the-loop when agreements are finalized.

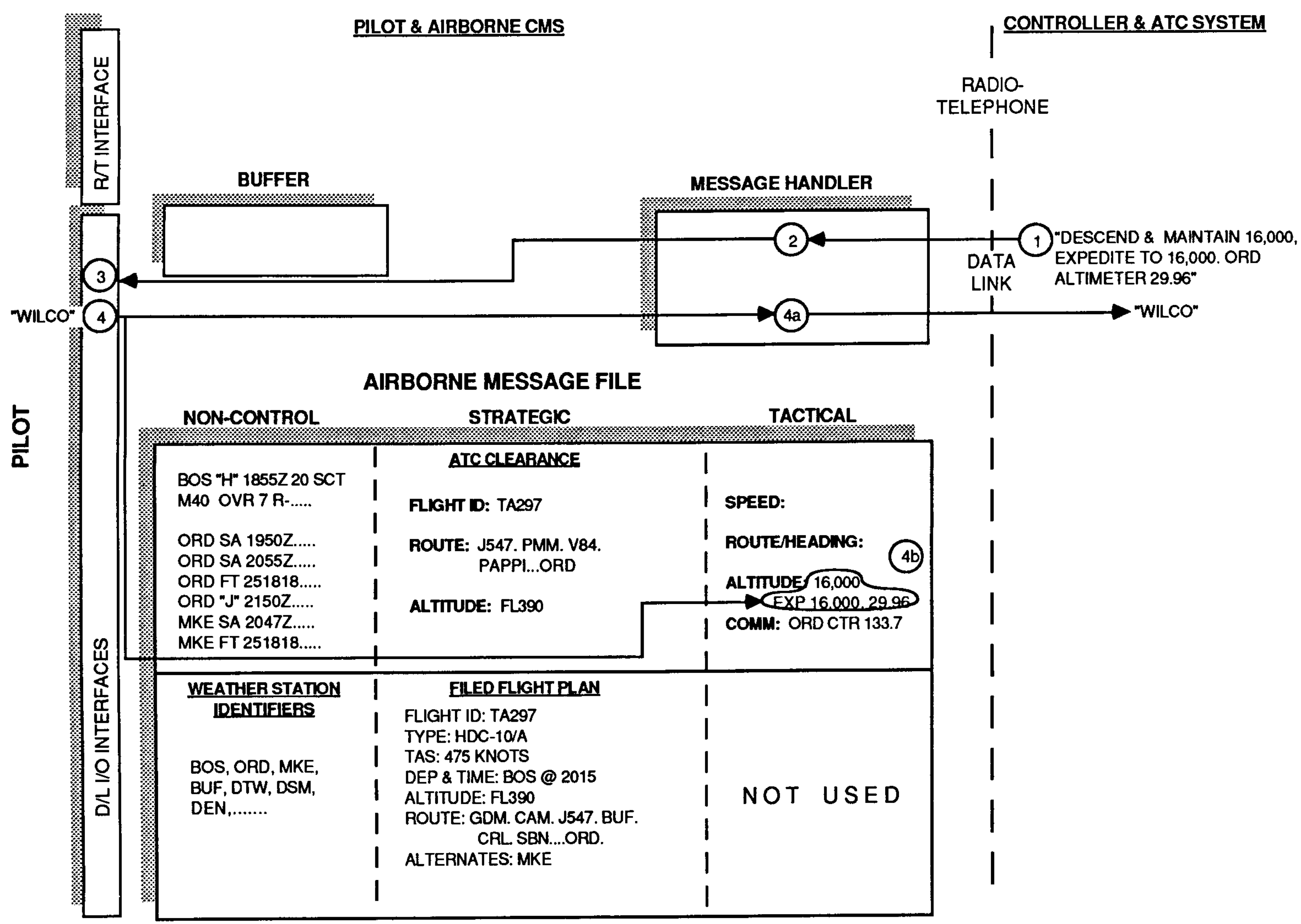

FIGURE B-16
D/L DESCENT INSTRUCTION WITH RATE REQUEST

Time: 2212Z
Location: Just west of Pullman VOR (PMM)

Descriptive Text for Figure B-16: This figure illustrated how the controller or ATC system could use "modifiers" in a message to achieve a desired objective. The contents of the AMF just prior to this message reflect the following d/l exchanges which have taken place in the r/t scenario since the previous figure:

Time	Exchange
2203Z	TA297 instructed to contact Chicago Center on 133.7.
2204Z	TA297 picks up O'Hare ATIS information "J".
2206Z	TA297 instructed to descend and maintain FL200.

In Step 1, the controller issues an instruction for the pilot to descend and maintain 16,000 feet, and to expedite the descent all the way to 16,00 feet (There may be cases where the controller needs only part of the descent to be completed expeditiously: as an example "descend to 16,000, expedite down through FL200."). After processing and forwarding the message to the pilot interface (Step 2 and 3), the pilot indicates compliance by issuing the WILCO response, which causes the CMS to issue a d/l WILCO message and update the appropriate fields in the AMF. It should be noted that altimeter settings are always provided on the first descent instruction for the aircraft to descend below 18,000 feet. The ground system automatically appends this information to the tactical descent message.

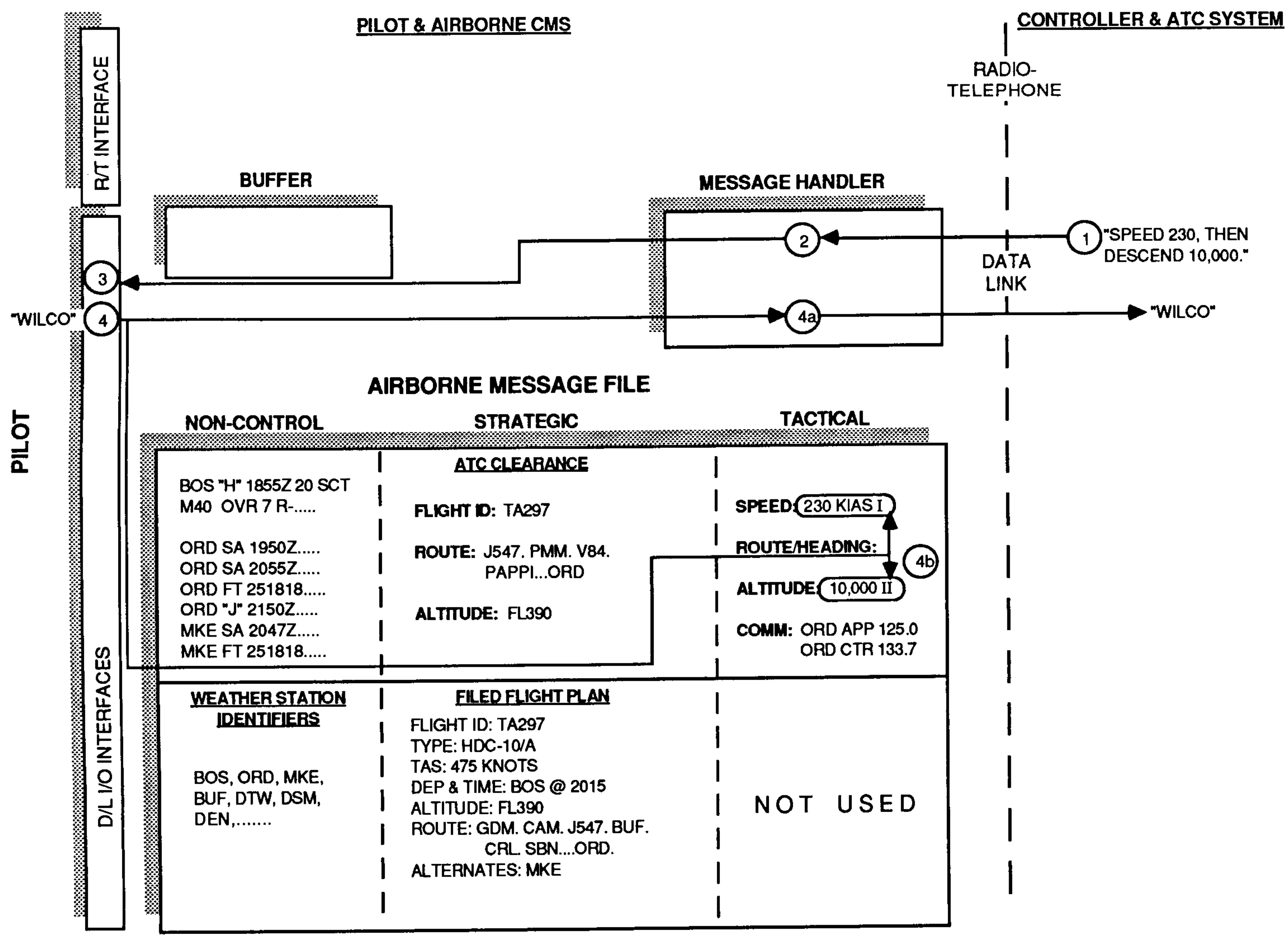

FIGURE B-17
D/L SPEED ADJUSTMENT AND DESCENT INSTRUCTION

Time: 2216Z
Location: Approximately 40 miles west of PMM VOR.

Descriptive Text for Figure B-17: In this example, TA297 has just been handed off to Chicago Approach and has completed the standard r/t check-in on the assigned frequency. At this point the controller issues a two-part tactical instruction on the flight to first reduce speed and then descend to 10,000 feet. (Simultaneous accomplishment of these two commands would be difficult, hence the controller must prioritize their execution). The two-part message is transmitted to the aircraft, and after the pilot WILCOs the message the appropriate parts of the AMF are updated, including the priority of performance. The priority of performance is indicated by the Roman Numerals I and II in the speed and altitude fields of the AMF.

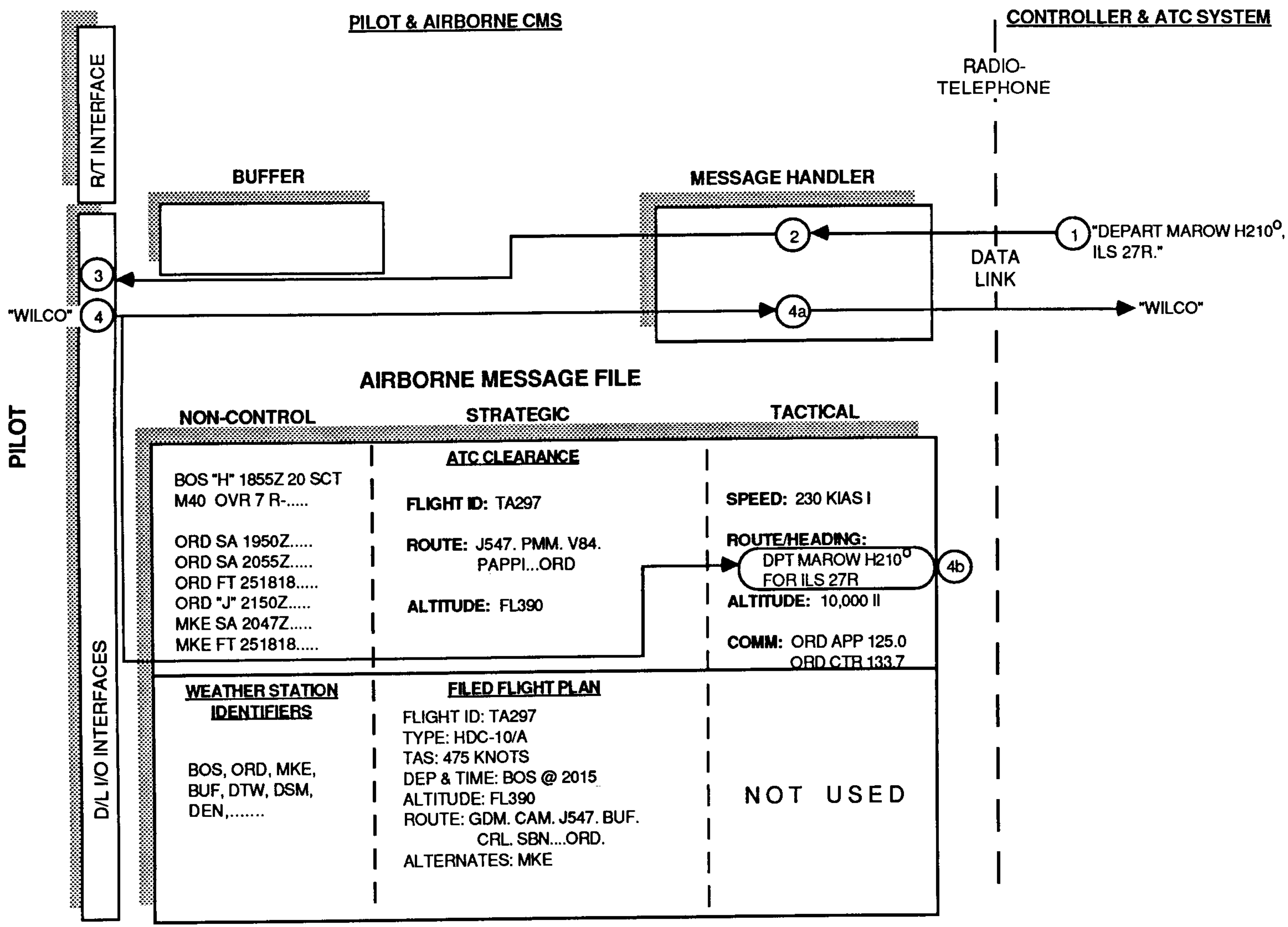

FIGURE B-18
TERMINAL AREA TACTICAL INSTRUCTIONS

Time: 2219Z
Location: Approximately 8 miles east of MAROW intersection

Descriptive Text for Figure B-18: In this figure a routine tactical message exchange is shown. However in this case the pilot is not expected to turn to the new heading until reaching MAROW intersection, and this fact is included as part of the message uplinked in Step 1. It should also be noted that the objective of the first off-route vector is also stated (in this case the vector is intended to lead the aircraft to the ILS approach for runway 27R). This provides the crew with a basis for planning future action should radio communications fail.

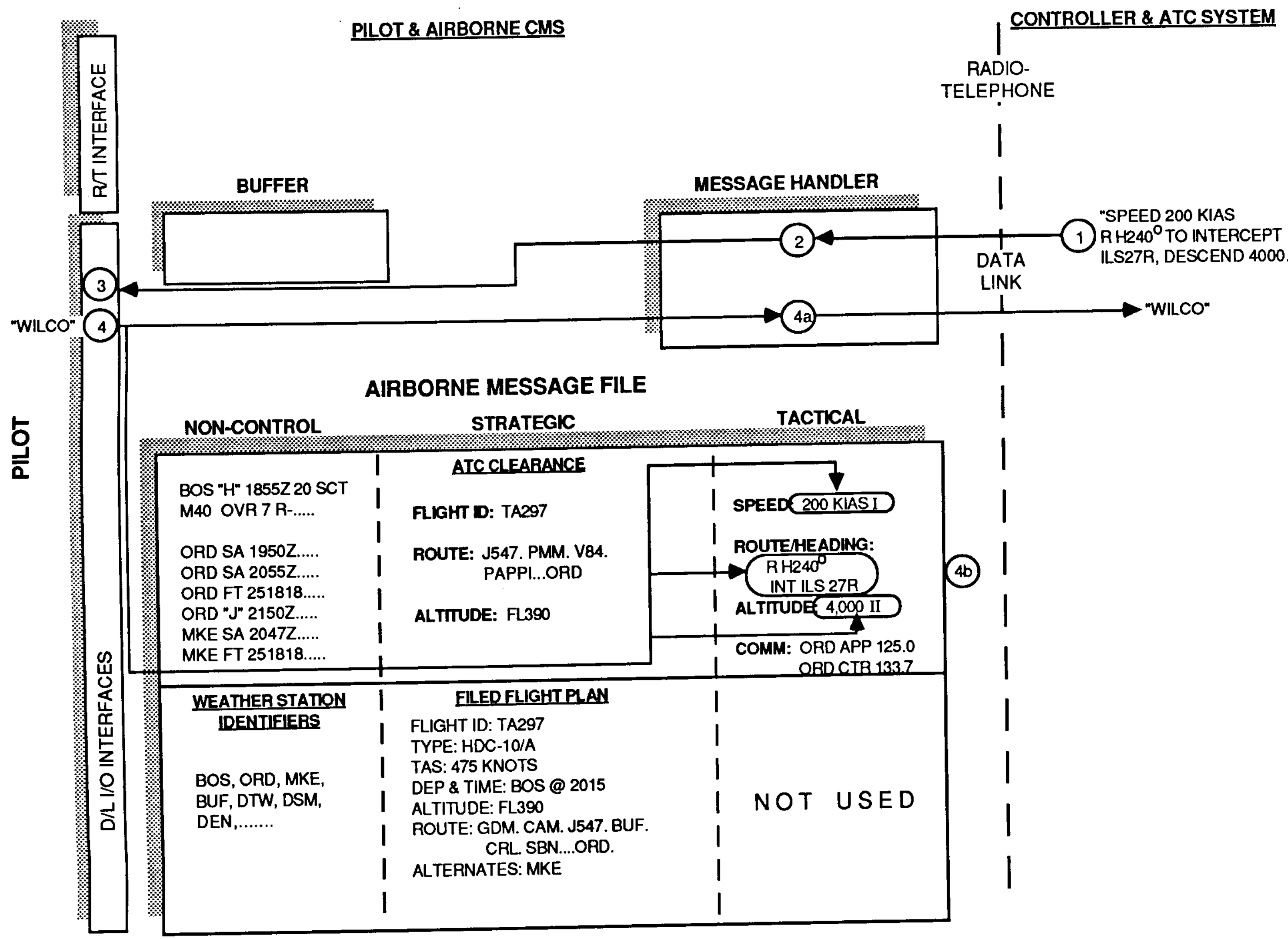

FIGURE B-19
MULTIPLE TACTICAL INSTRUCTIONS

Time: 2226Z
Location: Just north of final approach course for 27R

Descriptive Text for Figure B-19: This figure illustrates that multiple tactical instructions can be chained together and be treated in the same manner as other single, routine tactical messages.

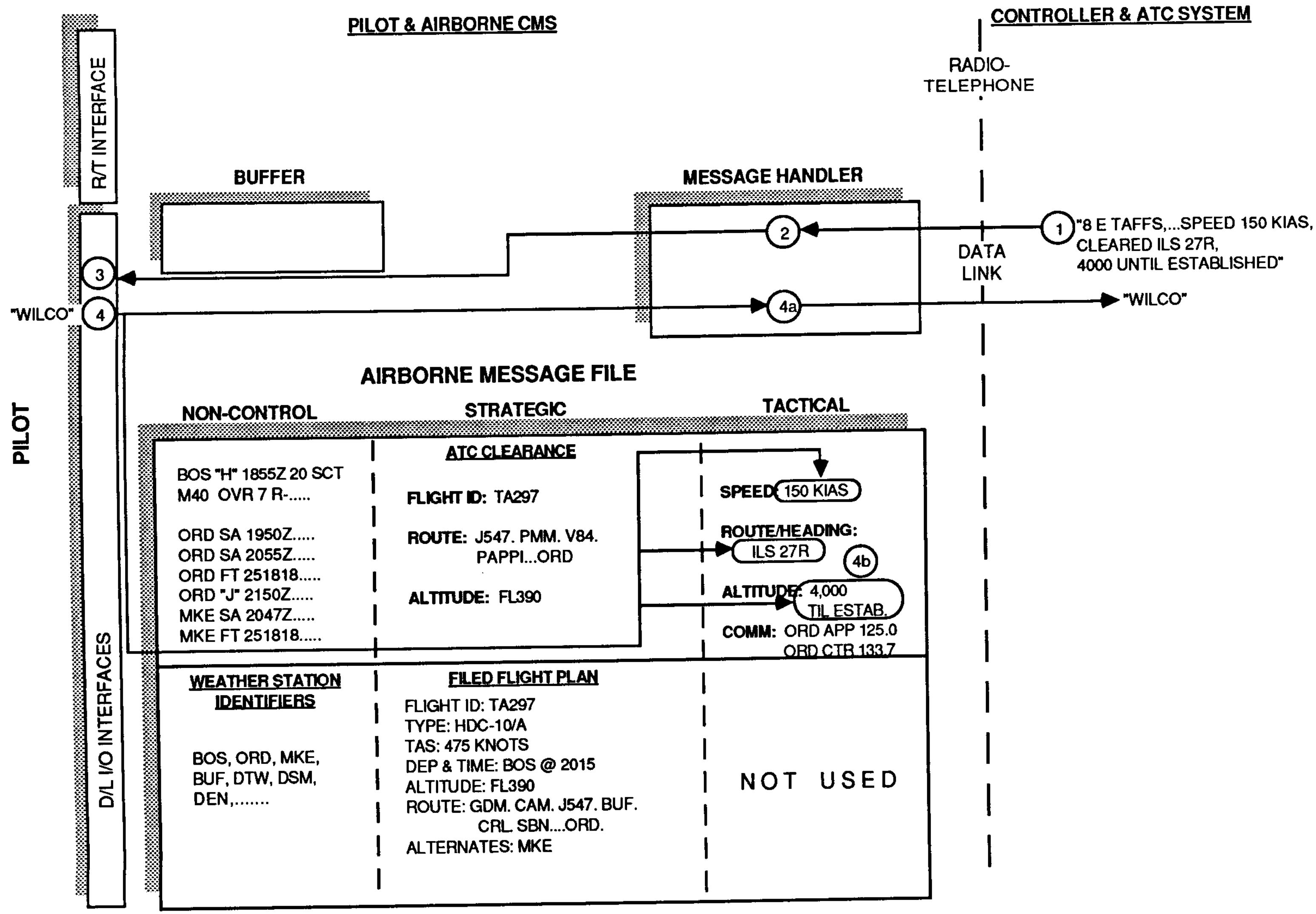

FIGURE B-20
APPROACH CLEARANCE

Time: 2229Z
Location: Approximately 8 miles east of TAFFS intersection

Descriptive Text for Figure B-20: This figure illustrates a routine tactical instruction and acknowledgement of approach clearance. Part of the uplink message is a report of the aircraft's position relative to a significant approach fix used for orientation purposes. Because this position information loses value quickly as time passes, it is displayed to the pilot when he reviews the tactical instruction, but is is not saved in the AMF.

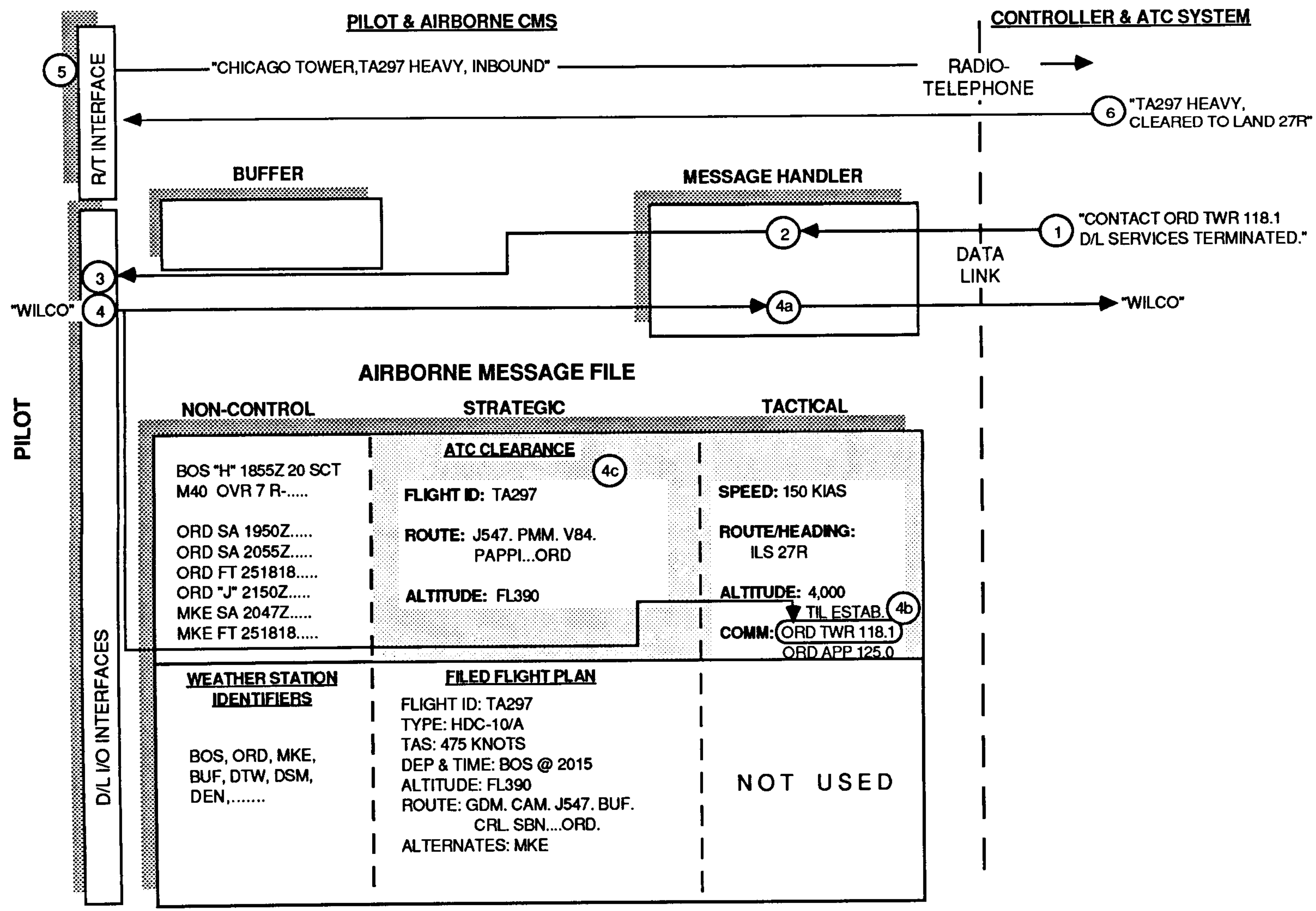

FIGURE B-21
TERMINATION OF D/L AND LANDING CLEARANCE

Time: 2233Z
Location: On final approach to ORD runway 27R.

Descriptive Text for Figure B-21: Figure B-21 shows a planned termination of d/l services combined with an instruction to contact another facility (Chicago Tower). The CMS takes the appropriate steps to flag affected data in the AMF (Step 4c), and the pilot and controller use r/t to conduct all message exchanges for landing and the subsequent taxi to the gate.

B.2 TA297 ORD-DEN

For the ORD-DEN segment of the hypothetical flight, it is again assumed that the flight plan reproduced below has been filed with the ATC system in advance of the flight.

Identification: TA297
Aircraft Type and Equipment: H/DC10/A
True Airspeed: 475 Knots
Departing: ORD
Proposed Departure Time: 2344 UCT
Cruising Altitude: FL390
Route of Flight:

ORD7.ORD.DBQ.J94.ONL.J114.....DEN

(Read as O'Hare 7 Departure to Dubuque VOR J94 to O'Neill VOR J114 to Denver).

Estimated Time En route: 2:10
Alternate Airports: None.

As for the r/t scenario of Appendix A, it will be assumed that TA297 will be cleared to Denver on a different route than the one it had originally filed. The crew will accept this different clearance, but once airborne will try to seek amendments to the strategic agreement to bring it into closer conformance with the filed flight plan route. The proposed amendments are more substantial than the simple modifications proposed during the BOS-ORD segment (See Figure A-3).

Many of the exchanges illustrated in Figures B-22 through B-35 have already been discussed in the BOS-ORD segment of the scenario. The reader will be directed to the similar earlier examples in these cases, while emphasis in this part of the scenario will be placed on variations in the exchange process.

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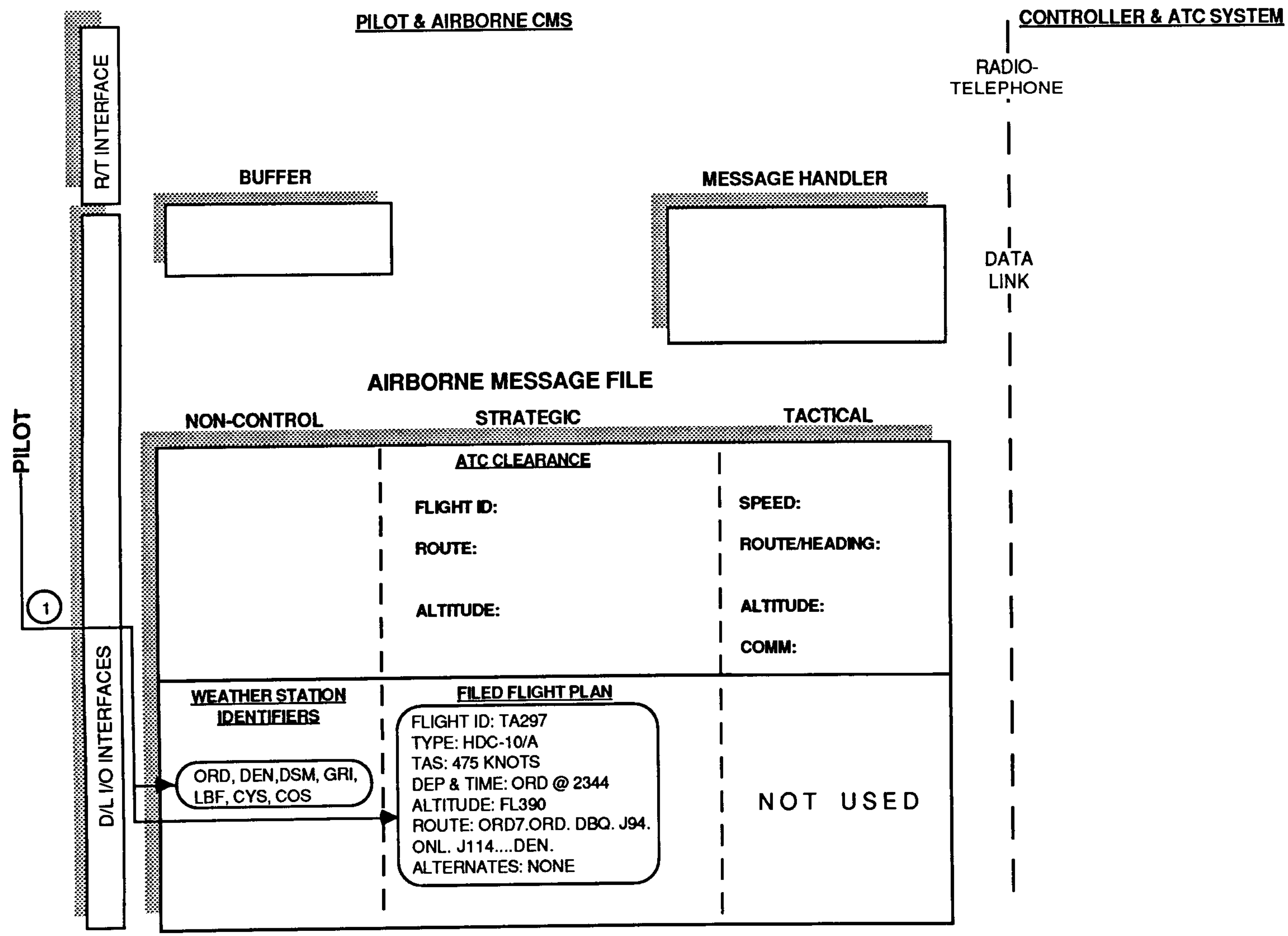

FIGURE B-22
PREFLIGHT INITIALIZATION

Time: 2310Z
Location: At ORD Gate F-7

Descriptive Text for Figure B-22: In this figure, the contents of the AMF static data area are shown after the pilot has completed the initialization process. The filed flight plan and weather station identifiers are inserted manually by the pilot prior to engaging in d/l exchanges with the ground system.

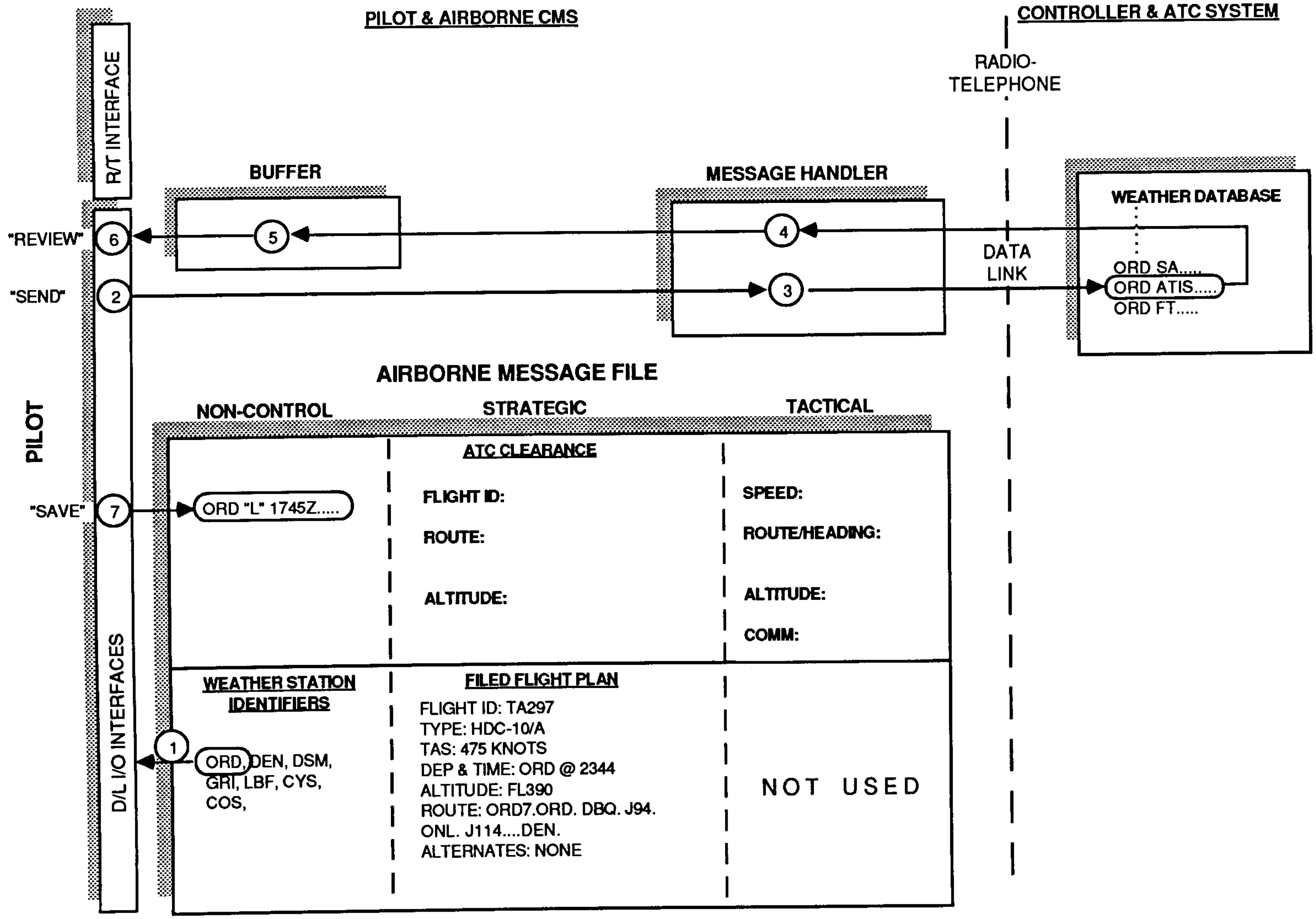

FIGURE B-23
REQUESTING DEPARTURE ATIS

C-3

Time: 2315Z
Location: At ORD Gate F-7

Descriptive Text for Figure B-23: In the same manner described for Figure B-2, the crew issues a d/l request for the departure ATIS information at ORD. After the pilot reviews and saves the uplinked ATIS message, it is entered in the appropriate AMF storage field for later use or referral by other parts of the airborne system.

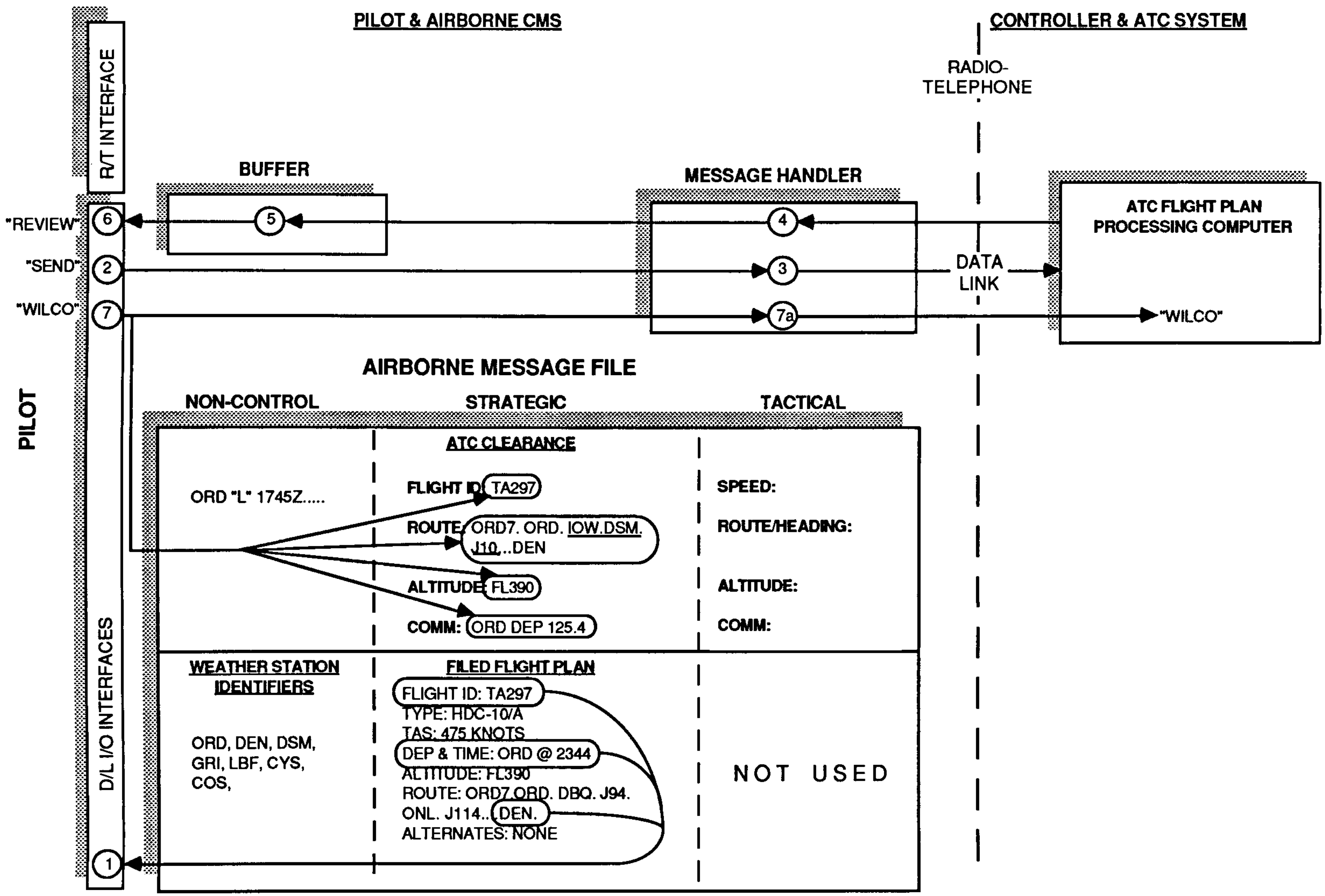

FIGURE B-24
REQUESTING / RECEIVING IFR CLEARANCE

Time: 2325Z
Location: At ORD Gate F-7

Descriptive Text for Figure B-24: This figure shows the exchanges which took place as TA297 placed a d/l request to pick up its IFR clearance to Denver. The process is largely the same as described for Figure B-3, including the issuance of a clearance by ATC which differs somewhat from the filed flight plan. The CMS underscores these differences to make them stand out to the pilot. Figure A-3 shows the filed, cleared, and actual routes flown by TA297 in this hypothetical situation.

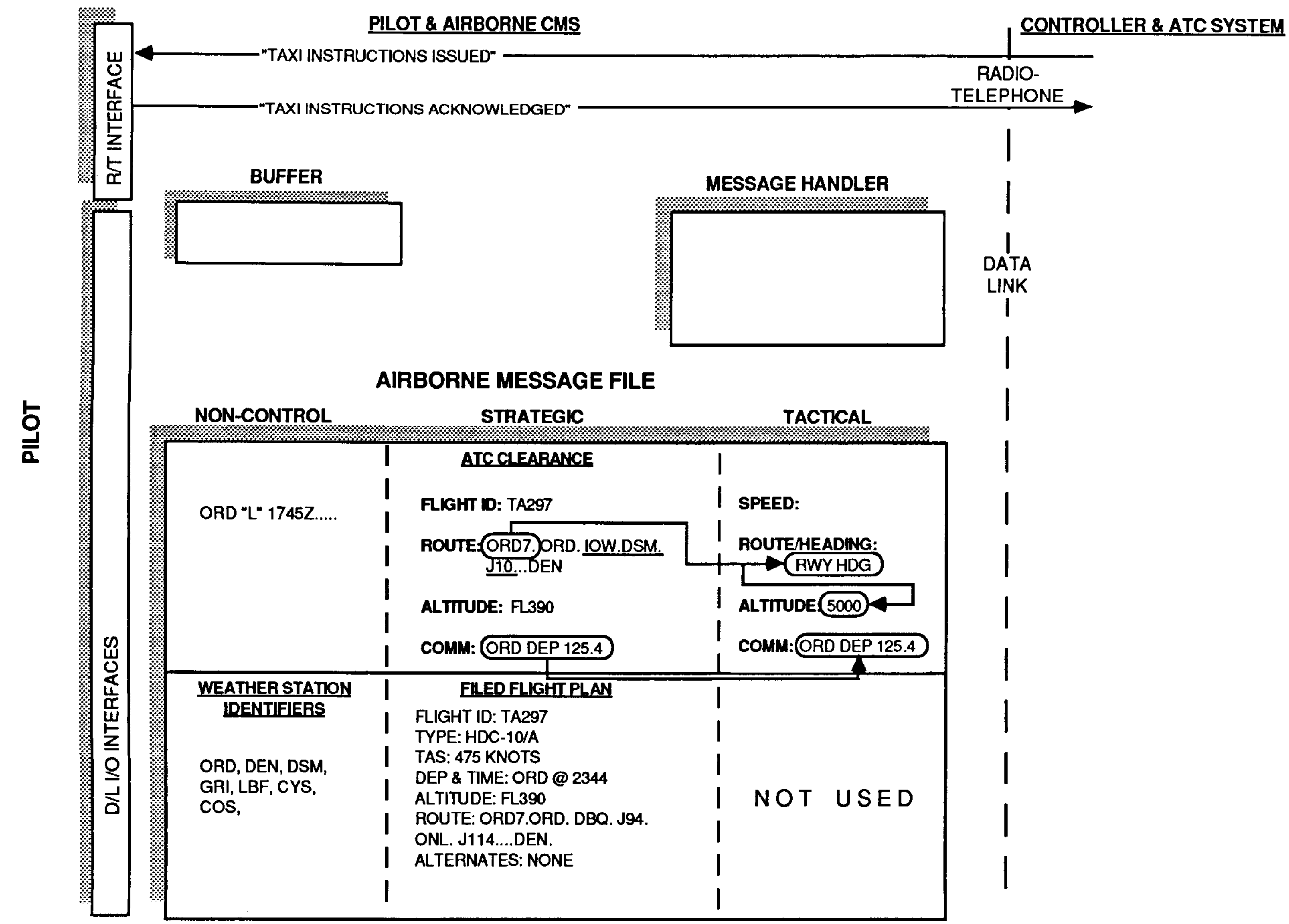

FIGURE B-25
TAXI AND TAKEOFF PREPARATIONS

Time: 2350Z
Location: Taxiing out to Runway 32L at ORD

Descriptive Text for Figure B-25: It is again assumed that taxi and takeoff instructions are issued and acknowledged via standard r/t techniques. As the aircraft taxis out the CMS extracts the pertinent data from the current strategic agreement and inserts this information in the appropriate fields of the tactical data storage area. In the BOS-ORD segment, an example was given where the term "LOGAN3" (the name of the assigned standard instrument departure) was merely inserted in the altitude and heading fields of the AMF tactical data area (Figure B-4). This required the pilot to have a printed textual description of the LOGAN3 to know the applicable headings and altitudes. To show how a more advanced airborne system may handle this, it will be assumed for Figure B-25 that the aircraft is equipped with an advanced on-board navigation database with complete descriptions of all U.S. SIDs, STARs, and IAPs. To make the pilot's task easier, the CMS may refer to the airborne navigation database to determine applicable headings and altitudes and insert these values in the AMF tactical data area. This would obviate the need for the pilot to cross-reference a printed textual description.

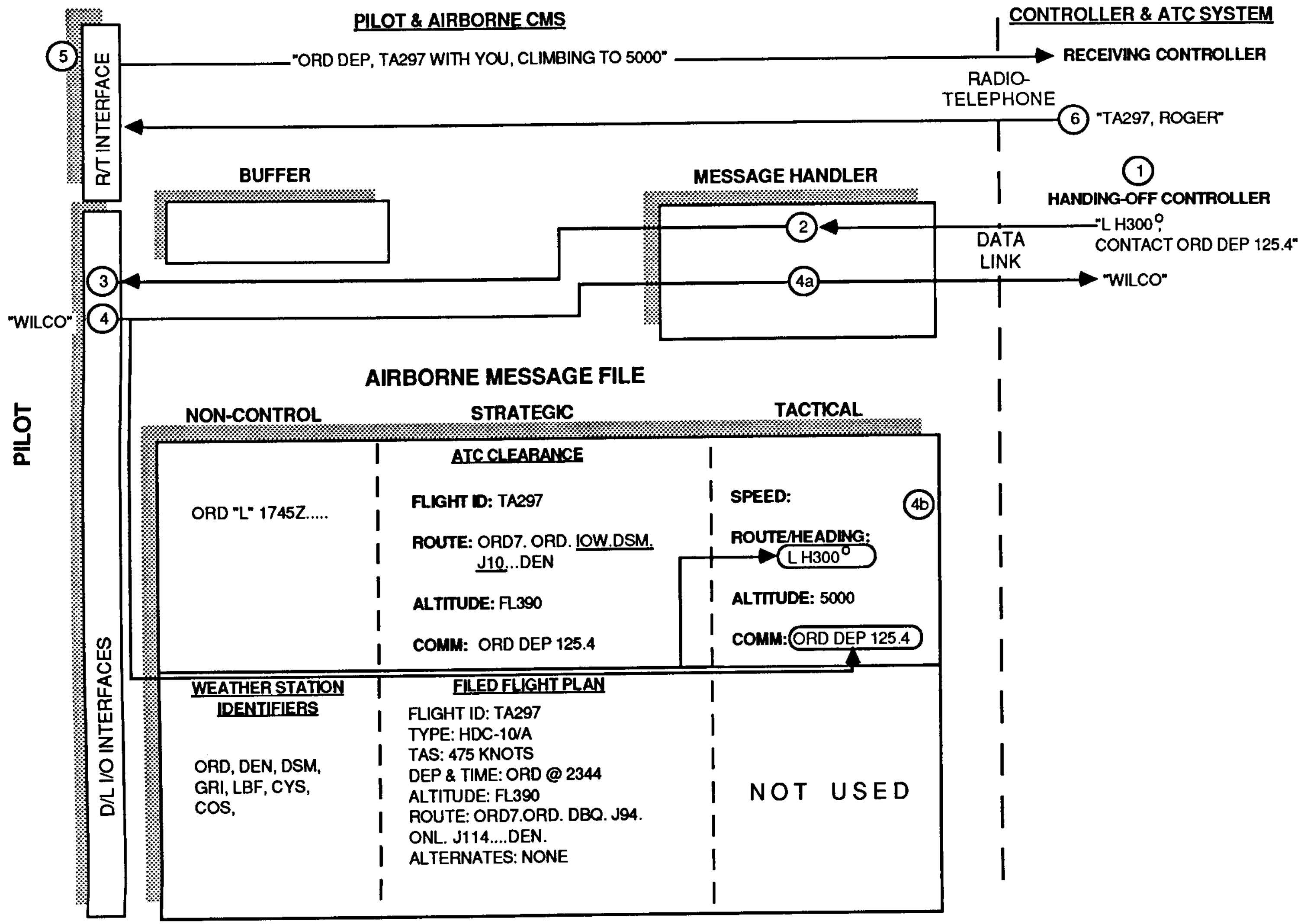

FIGURE B-26
DEPARTURE COMMUNICATIONS HANDOFF

Time: 2356Z
Location: On takeoff from ORD Runway 32L

Descriptive Text for Figure B-26: At this point TA297 is being handed off to another facility (ORD Departure) shortly after receiving its takeoff clearance. In this case the local controller issues a combined handoff and heading instruction in one message. The subsequent actions of the pilot and CMS are the same as those described for Figure B-5.

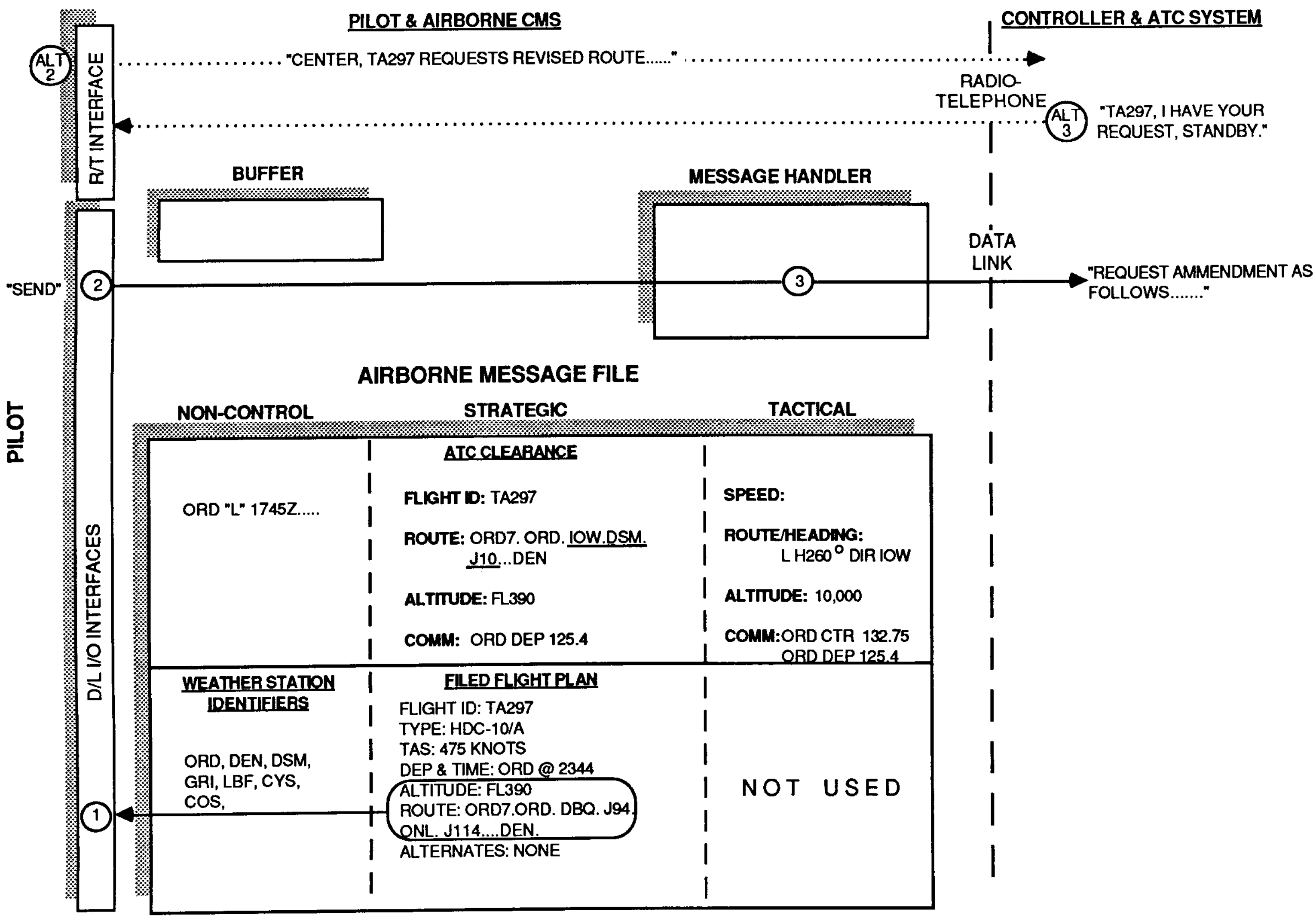

FIGURE B-27
AIR-INITIATED REQUEST TO AMEND STRATEGIC AGREEMENT

Time: 0004Z
Location: On initial climb

Descriptive Text for Figure B-27: In this and the following figure, the exchanges which might take place as the pilot and controller negotiate an amendment to an established strategic agreement are illustrated. Figure B-27 describes possible ways the pilot may initiate this process. It should be noted that the contents of the AMF have been revised to reflect the d/l exchanges which have taken place since the last figure (as noted below):

Time	Exchange
2356Z	TA297 checks-in with ORD Departure, and instructed to climb to 10,000.
2358Z	TA297 instructed to turn left to a heading of 260°, and proceed to IOW VOR when able
0001Z	Controller issues standard VFR traffic advisory.
0001Z	TA297 instructed to contact ORD Center on 132.75.
0002Z	TA297 issues "off" report to company.

Figure B-27 illustrates the two possible ways the pilot may submit a request to amend a strategic agreement. He would first call out the filed flight plan from the AMF storage area onto the pilot interface to determine if he would still like to operate according to that plan, Step 1. (As an alternative with airborne systems which have the capability to construct "trial plans", the pilot could submit an amendment based on a trial plan, rather than the originally filed flight plan). After reviewing the proposed amendment on the interface, the pilot would instruct the CMS to send the amendment request message to the ground system (Step 2). The message handler would format the request, send it via d/l, and wait for an appropriate response from the ground. Because it may take some time for the ground system to coordinate and process the request, it may issue a "stand-by" message back to the airborne system to at least indicate that the request was received and is awaiting further disposition.

An alternative means of submitting the request is shown by Alternate Steps 2 and 3 in which the pilot uses r/t to issue the request and the controller uses r/t to indicate receipt. This might be used in simplified airborne systems where the pilot does not have a trial plan function and does not want to amend according to the originally filed flight plan. In issuing the r/t amendment request the burden of putting the request into a machine-readable format is on the ground system.

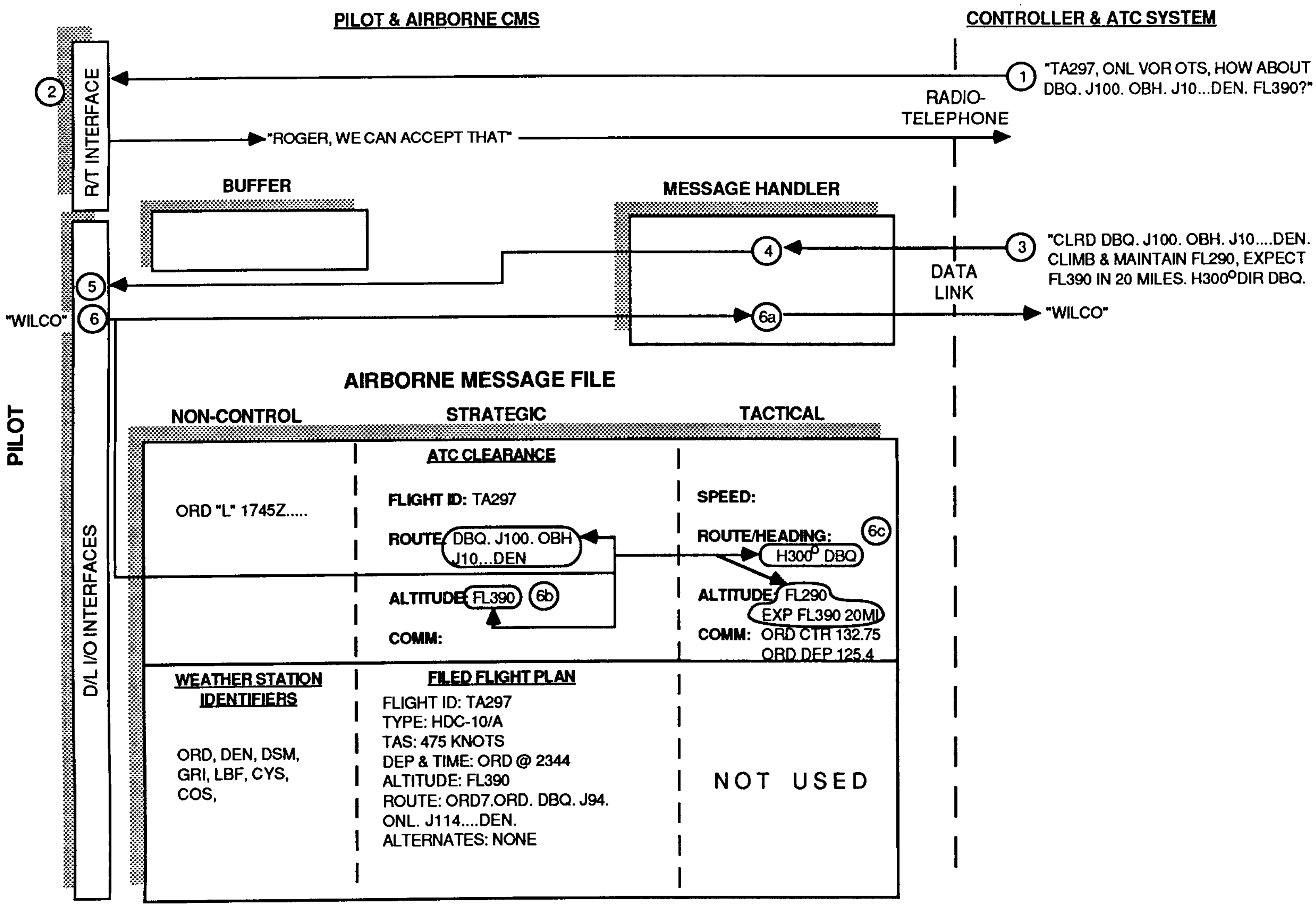

FIGURE B-28
NEGOTIATED AMENDMENT TO STRATEGIC AGREEMENT

Time: 0010Z
Location: Just east of DBQ VOR

Descriptive Text for Figure B-28: In this hypothetical scenario it was assumed that the ATC system could not honor the amendment request submitted by TA297 in the previous figure due to an inoperative navaid (ONL VOR). To resolve this problem, Figure B-28 illustrates how the pilot and controller use r/t to exchange interim proposals and solidify the negotiated agreement on d/l. After the controller gains pilot concurrence on the new amended strategic plan (Steps 1 and 2), he issues a d/l amendment instruction (Step 3). The message handler processes the message and forwards it to the interface for pilot review and action. The pilot's WILCO response causes the CMS to issue a WILCO acknowledgement back to the ground (6a) which closes out this series of d/l and r/t exchanges and establishes the amendment as the new operative agreement. The CMS also updates the appropriate areas of the AMF (Steps 6b and 6c). It should be noted that the controller appended initial tactical instructions (heading and altitude) to transition the flight to the new strategic route assignment.

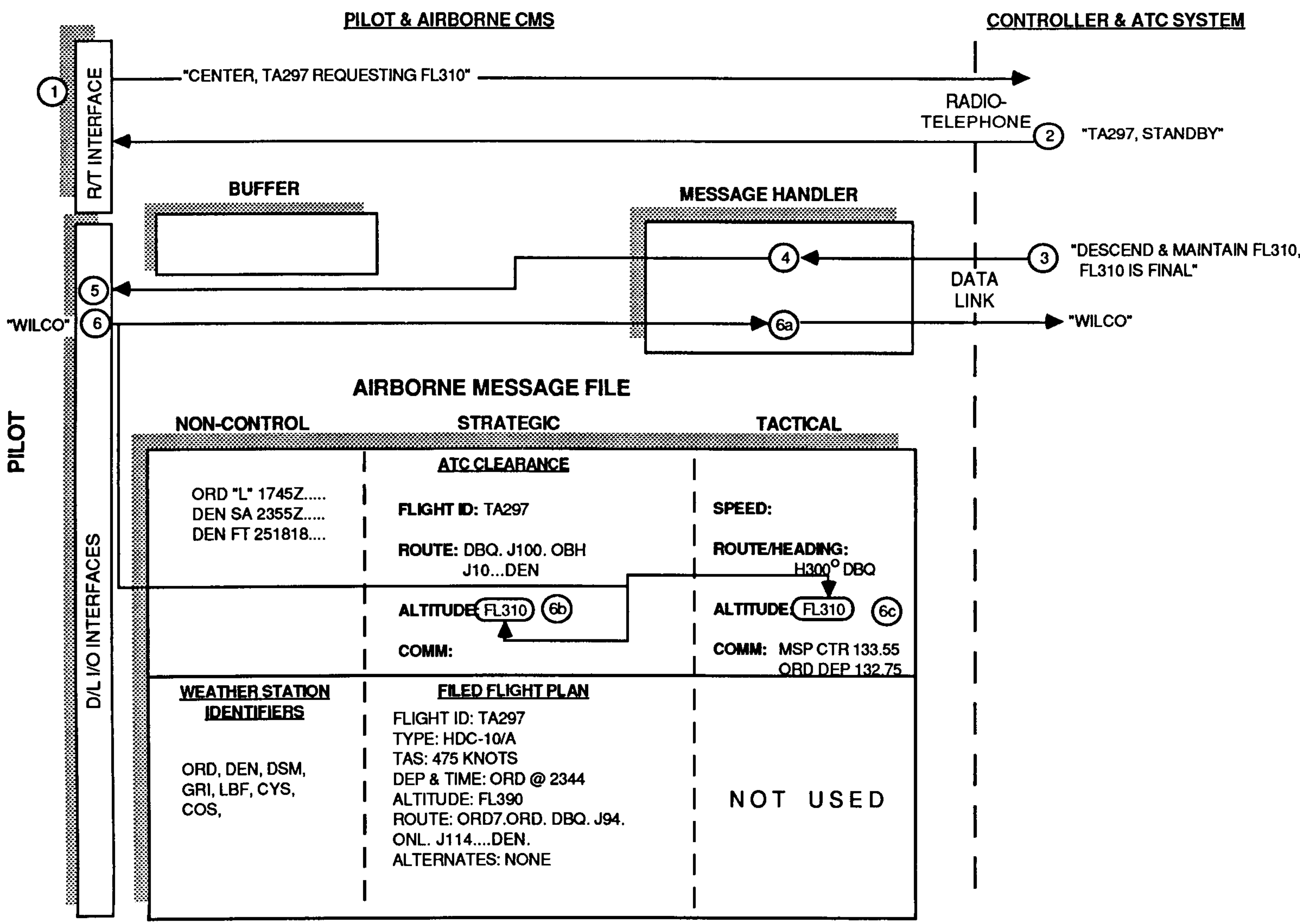

FIGURE B-29
REQUEST TO CHANGE CRUISING ALTITUDE

Time: 0010Z
Location: Over Wolback (OBH) VOR

Descriptive Text for Figure B-29: In the interim time between the last figure and this figure, TA297 was issued tactical instructions and requested weather data in the following tabulated exchanges:

Time	Exchange
0016Z	TA297 instructed to climb to FL390.
0044Z	TA297 handed off to Minneapolis Center on 133.55.
0050Z	TA297 requests and receives latest DEN weather and terminal forecasts; also issues a pilot report on observed conditions aloft.

The contents of the AMF in Figure B-29 reflect these exchanges.

As the flight nears OBM VOR it begins encountering light turbulence and inquires (via r/t) about turbulence at other altitudes. The controller responds (also via r/t) that a B727 about 80 miles ahead reported a smooth ride at FL310. Therefore, the crew issues an r/t request to change cruising altitude to FL310, the receipt of which is acknowledged on r/t by the controller (Steps 1 and 2). The controller grants consent to descend to FL310 by issuing a d/l message. The notation in the message that "FL310 is final" indicates that this is a change in the strategic agreement, and that FL310 will be the expected cruising altitude for the duration of the flight.

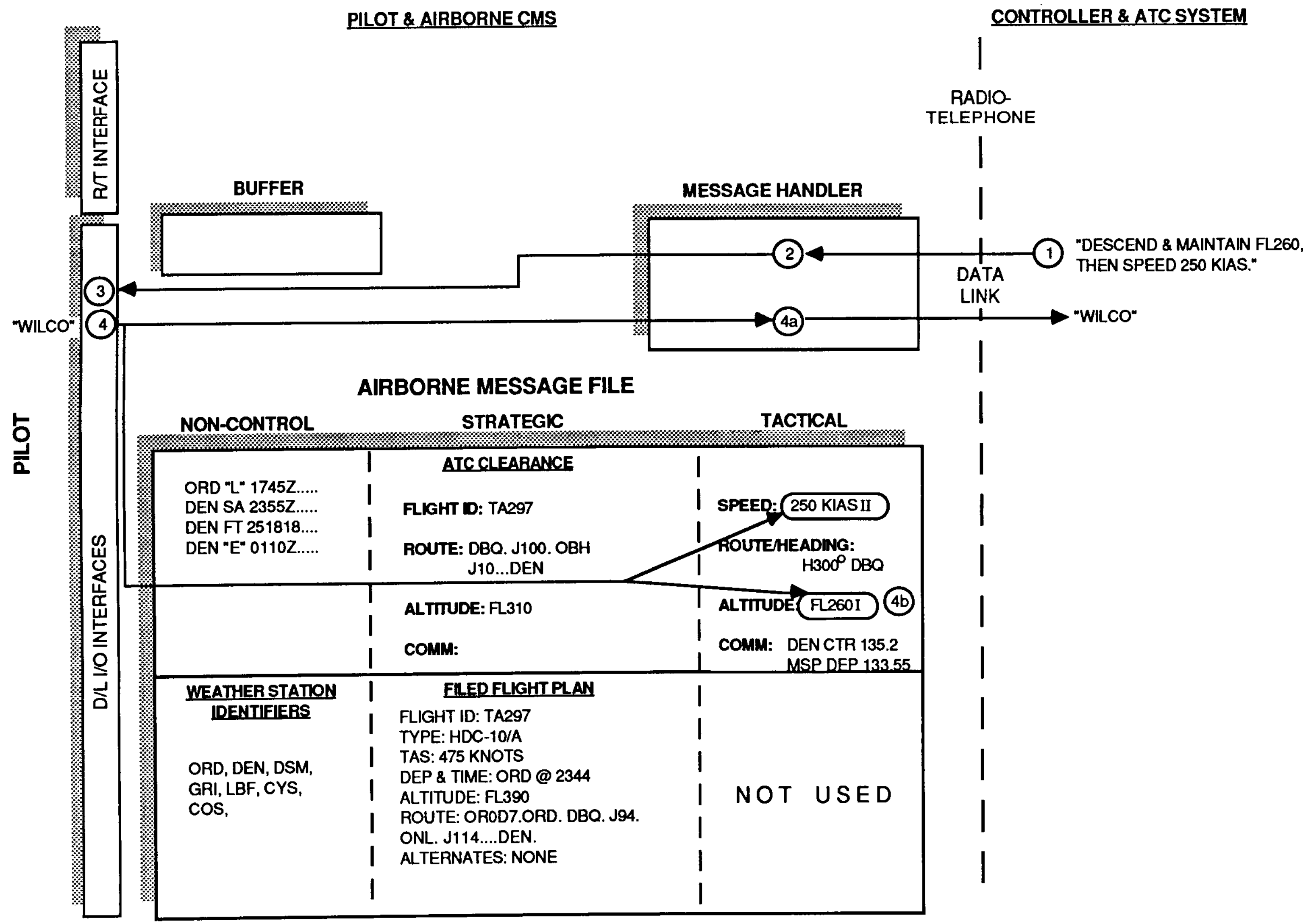

FIGURE B-30
INITIAL DESCENT & SPEED INSTRUCTIONS

Time: 0135Z
Location: On initial descent into DEN terminal area

Descriptive Text for Figure B-30: In this figure TA297 is instructed to first descend to FL260 and then to reduce speed to 250 knots. This prioritization is indicated by the Roman Numerals accompanying these entries in the AMF. The contents of the AMF also reflect these exchanges which occurred just prior to the one depicted in Figure B-30.

Time	Exchange
0120Z	TA297 handed off to DEN Center on 135.2.
0130Z	DEN Center advises TA297 (via r/t) to plan for the profile descent into DEN.
0135Z	TA297 picks up arrival ATIS "E".

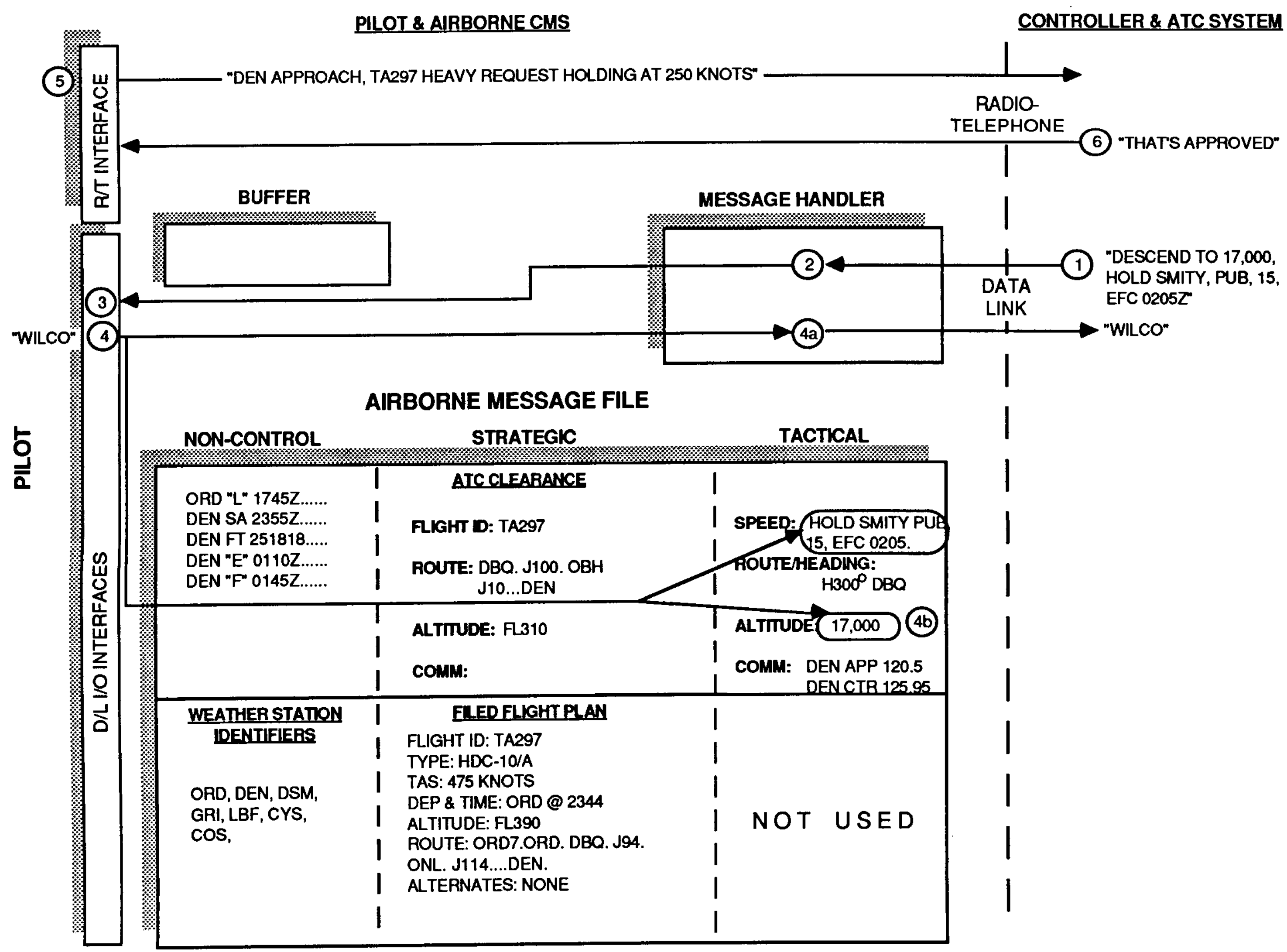

FIGURE B-31
TACTICAL HOLDING INSTRUCTIONS

Time: 0149Z
Location: On the profile descent into DEN

Descriptive Text for Figure B-31: Weather and traffic saturation near DEN airport necessitate the issuance of holding instructions as outlined in Figure B-31. Since the previous figure TA297 has been engaged in the following exchanges which are reflected in the contents of the AMF:

Time	Exchange
0136Z	TA297 handed off to next DEN sector on 125.95.
0140Z	TA297 cleared for profile descent; instructed to descent to 12,000.
0145Z	TA297 handed off to DEN approach on 120.5.
0148Z	TA297 picks up new arrival ATIS "F".

In Figure B-31, holding instructions are issued to and acknowledged by TA297. The flight will be expected to hold at SMITY intersection as published with 15 mile DME legs; further clearance can be expected at 0205Z. With the WILCO response by the pilot, the holding instructions are entered into the appropriate fields of the AMF. Steps 5 and 6 show how the pilot might request deviation from the maximum authorized holding speed of 230 knots at 17,000. This deviation request and acknowledgement is completed entirely on r/t.

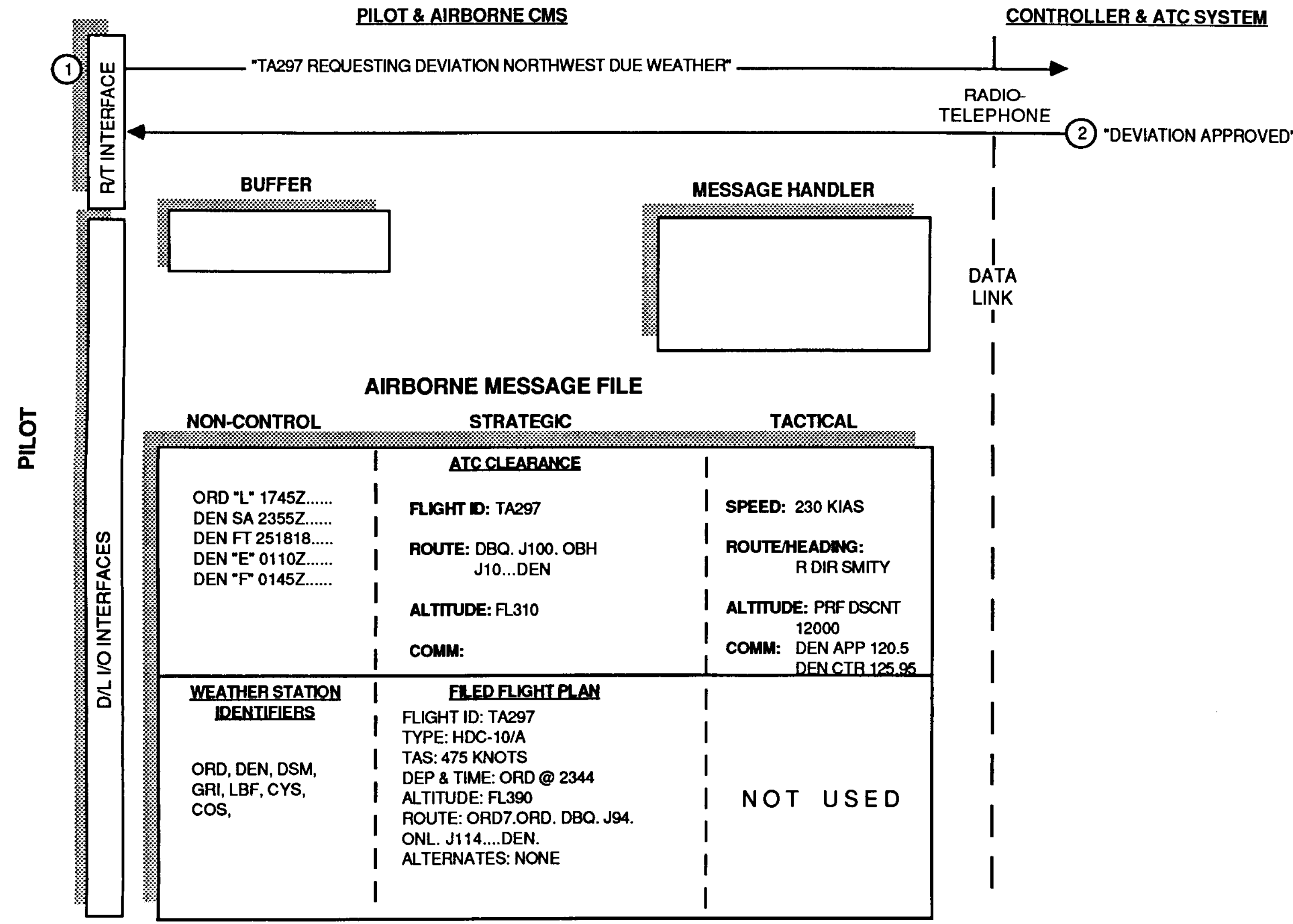

FIGURE B-32
REQUEST FOR WEATHER DETOUR

Time: 0210Z
Location: Inside SMITY intersection on the profile descent.

Descriptive Text for Figure B-32: If the flight needs to detour around convective weather, it issues requests and receives acknowledgements using standard r/t techniques, and shown by Steps 1 and 2 in Figure B-32. The contents of the AMF are not affected as these detours are assumed to be short-term in nature. Once the need to detour has passed, the controller could issue tactical d/l instructions to return the aircraft to the desired route. In Figure B-32 it should be noted that the contents of the AMF reflect the following exchanges which took place subsequent to Figure B-31.

Time	Exchange
0157Z	TA297 advises company of probable delay due to hold.
0204Z	TA297 instructed to continue with profile descent down to 12,000, and maintain 230 knots in descent.

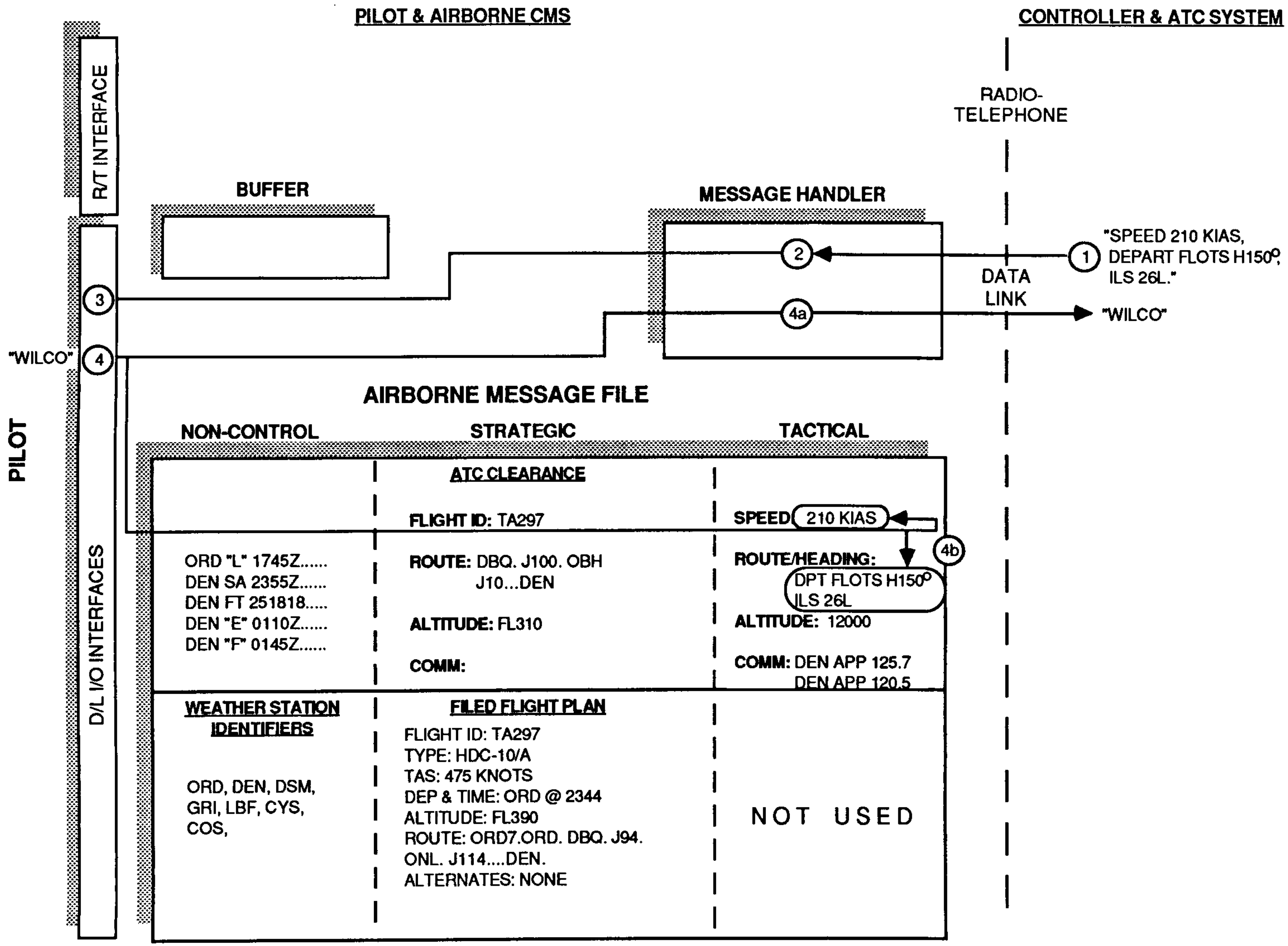

FIGURE B-33
TERMINAL AREA MANEUVERING INSTRUCTIONS

Time: 0215Z
Location: Just northeast of FLOTS intersection

Descriptive Text for Figure B-33: TA297 is issued terminal maneuvering instructions (including additional speed commands) in preparation for the ILS approach to Runway 26L. Prior to this exchange TA297 was handed off to another DEN approach sector on 125.7.

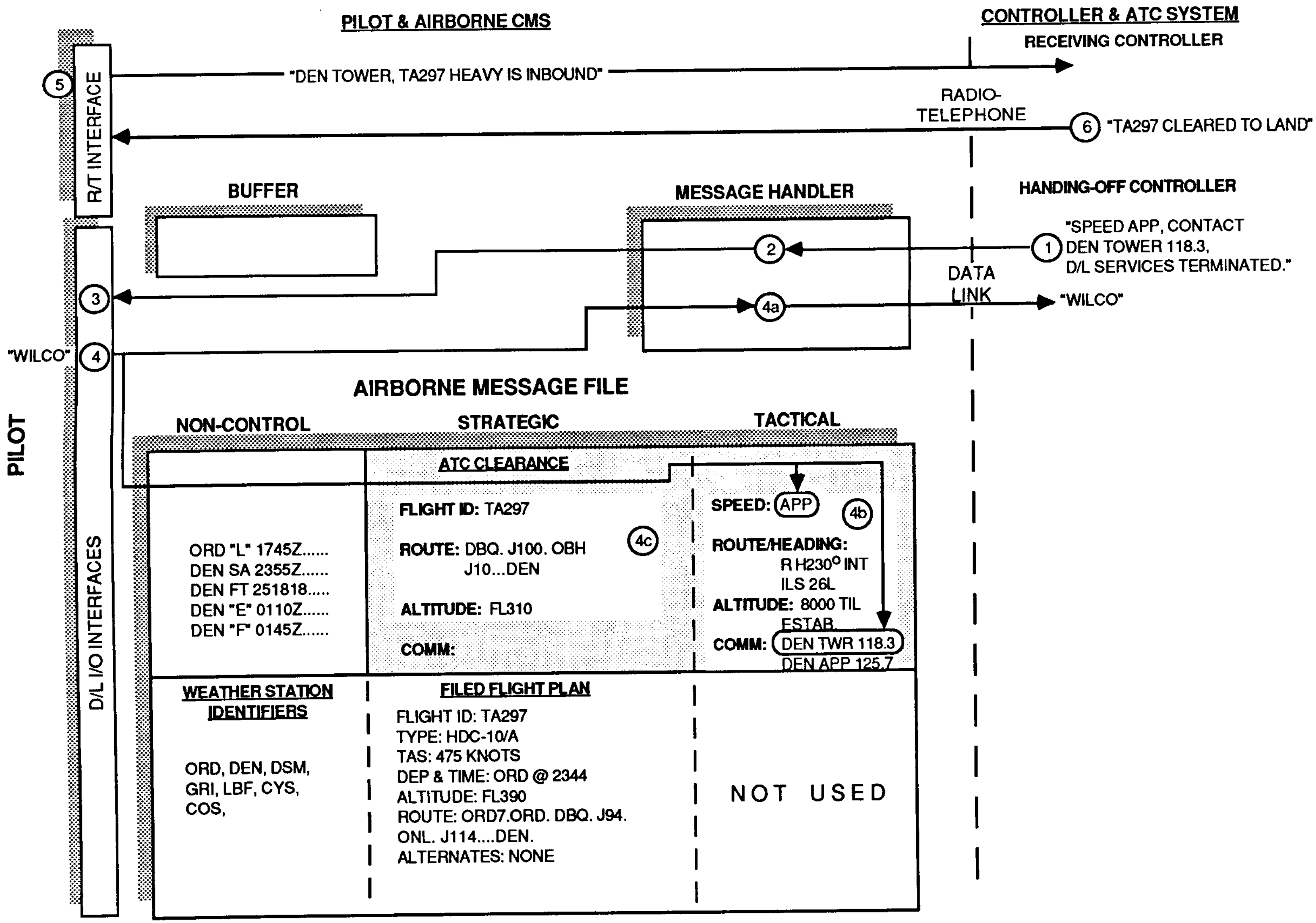

FIGURE B-34
TERMINATION OF D/L AND LANDING CLEARANCE

Time: 0220Z
Location: On final approach to Runway 26L at DEN

Descriptive Text for Figure B-34: This figure illustrates a planned termination of d/l services coinciding with a handoff to the next facility (in this case DEN Tower). Prior to the d/l exchanged outlined in Figure B-34, TA297 was issued d/l instructions to turn to a heading of 230° to intercept the localizer, cleared for the ILS approach, and maintain 8,000 feet until established on the localizer. In step 1 of Figure B-34, TA297 is instructed to reduce to its approach speed (APP), as well as to contact the DEN Tower. Once the message is WILCOed by the pilot (Step 4), the CMS flags the affected fields in the AMF. The pilot and receiving controller conduct remaining exchanges (such as landing clearance) using standard r/t techniques.

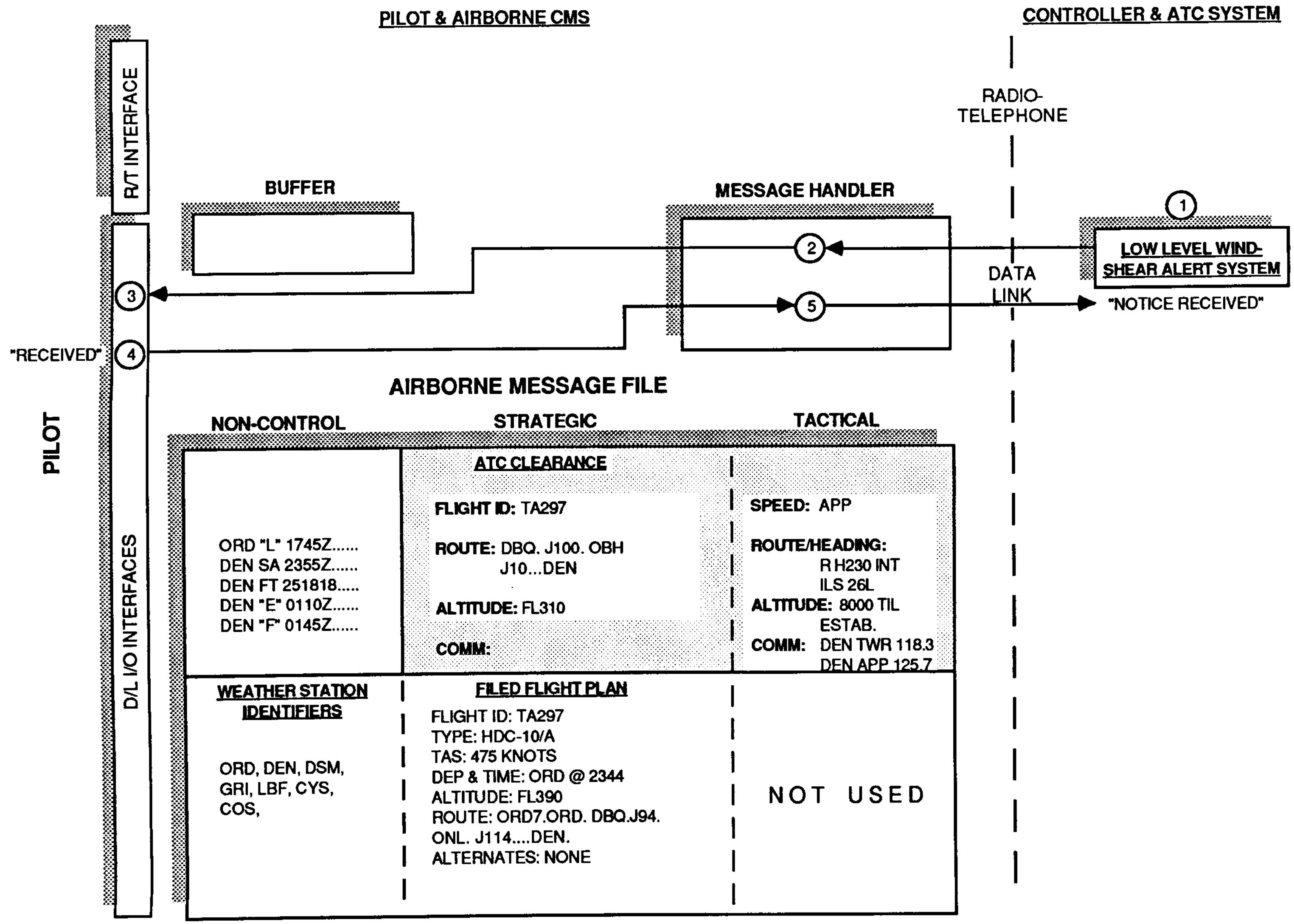

FIGURE B-35
URGENT HAZARDOUS WEATHER ADVISORY

Time: 0222Z
Location: On short final approach to Runway 26L at DEN

Descriptive Text for Figure B-35: In the scenario as the flight approached Runway 26L the Low-Level Wind Shear Alert System detected a potential wind shear hazard. To address this situation the ground system could be designed to automatically uplink the hazard advisory to d/l-equipped aircraft, Step 1. (It is assumed that the d/l remains physically capable of supporting these exchanges, even though its use for tactical and strategic messages has been terminated). After processing and forwarding the hazard message to the interface (Steps 2 and 3), the pilot simply issues a "notice received" message back to the ground. In this way the ground system can be assured the hazard message made it all the way to the pilot. There is no apparent value in saving these local hazard messages, so no action is taken to store the message in the AMF.

APPENDIX C

A CATALOG OF STANDARD ATC MESSAGES

This appendix provides a catalog of ATC messages for which standard formats and phraseologies have been specified in References 19, 20, and 21. Also included are postulated messages which could be expected in the application of advanced ATC techniques such as time-based metering and spacing or long-distance direct routing. The intent of building the catalog was to make certain that all messages which are currently transmitted on r/t, as well as those which can be anticipated in an advanced ATC environment, are at least given initial consideration as candidates for exchange on d/l. To ensure that the resulting catalog was a comprehensive list of possible messages for d/l, no initial judgment was made during the compiling of the catalog on whether a given message would be suitable for exchange on d/l. As a result, the catalog contains many messages which are not likely to be exchanged on d/l. However, the smaller subset of messages which are viable candidates for exchange on d/l are fortunately those which are used most frequently during the course of nominal flights.

In reviewing the catalog, primary attention should be directed to the information content and the intent of a given message, as these attributes most directly affect the physical structure of the message and the procedures used to exchange it on d/l. For example, there are several "families" of messages in which the basic format is the same, with variables in the message assigned values to address a given situation. For these families, it may be advantageous to condense the non-variable parts of the message into a more-efficient coding scheme than a one-for-one character-string encoding. In addition, the intent of a message dictates the type of procedures used to exchange it (on either r/t or d/l). For this reason, the messages in this catalog are organized according to the three types described in Section 2 of this report, namely: strategic messages, tactical messages, and non-control information messages. However, apart from the compiling and organizing the set of all possible messages into these three types, and further reducing them into families where possible, the actual coding of messages for digital transmission is left for future research.

For brevity, only the "uplink" version of a message (i.e., those which are transmitted from ground to air) are listed for most cases. This is consistent with the general flow of messages in the current ATC system, in that once the system knows the objective of a given flight, it issues instructions and information to the aircraft to support that objective. As a result, the majority of message transactions are ground-initiated and upward in nature. If needed, pilots can use similar messages to issue requests to the ground system by rephrasing the message as a request, rather than as an instruction from the ATC system.

C.1 Strategic Messages

Table C-1 summarizes the basic information exchanged between the pilot and the ATC system in reaching strategic agreements. The strategic agreement, as noted in Section 2, is basically the IFR clearance, which authorizes a flight to operate as IFR traffic in the ATC system. It specifies an overall course of action from departure point to destination, including the route and altitude, plus contingency instructions if necessary. If radio communications are lost during the course of the flight, the strategic agreement becomes the operative agreement between the pilot and controller for the remainder of the flight.

The messages exchanged to reach strategic agreements fall into two basic categories: those used to reach an initial agreement and those used to amend an established agreement. The pilot usually initiates the process of reaching a strategic agreement as part of his preflight activities when he submits a flight plan to the ATC system and subsequently picks up an IFR clearance. In doing so he may interface with the ATC system directly or indirectly through telephone, or by an in-person visit, in addition to using standard r/t procedures. Therefore, rather than describing r/t formats for strategic messages, Table C-1 lists the information which is exchanged between the pilot and the ATC system.

TABLE C-1
STRATEGIC MESSAGES

1a. Information to Establish Initial Agreements - Initial IFR Flight Plan

Information	Examples	Comments/Usage
1. Aircraft/Flight Data		
a. Registration or Flight ID	N8086W, TW880, Pacer 62	This will become the aircraft's radio call sign for duration of flight. It also becomes a means by which the controller can access ATC system computer for information on this flight.
b. Aircraft Type	PA28, B727, F4	Provides controller/ATC system with means of establishing nominal performance capabilities and flight characteristics.
c. Avionics	VOR only, VOR/DME; Station-referenced 2D, 3D, or 4D RNAV; Earth-referenced 2D, 3D, or 4D RNAV;	Indicates the type of navigation capabilities on board and the preferred means of referencing navigation fixes.
	(r/t assumed); Mode S d/l with address; Other d/l with address;	Indicates communications capabilities and means of addressing aircraft for d/l exchanges.
	No transponder; Mode A, C, S;	Indicates type of system on board for surveillance purposes only.

TABLE C-1
(Continued)

Information	Examples	Comments/Usage
		Note: Current flight plan formats provide for a single character field to describe airborne avionics capability. In view of numerous emerging advanced airborne capabilities, it will likely be necessary to expand this field and separately describe navigation, communication, and surveillance capabilities as shown above.
2. Mission Objectives		
a. Departure Point and Time	IAD @ 1915Z (airport); CSN @ 1915Z (navaid); 38/56N 77/29W @ 1915Z (fix);	Describes originating point for proposed operation. It could be airport, navaid, or suitably defined navigation fix. ATC system forwards the clearance and flight information to appropriate facility/position based on these data.
b. Route and Destination	RV EMI V166 DQO V157 COL JFK; IAD JFK; IAD 40/48N 77/29W JFK	Specifies desired route and ultimate destination. Because navigation fixes would be referenced according to the aircraft's equipment, navigation capability could be inferred from this information rather than explicitly stated in avionics status.

TABLE C-1
(Continued)

Information	Examples	Comments/Usage
c. Altitude Profile	Cruising Altitude 9000; EMI 6000 LRP 9000 COL 9000;	Current flight plan formats make allowance to specify only a single cruise altitude. Some transoceanic formats allow specification of step-climb profiles; these profiles could be incorporated in future domestic flight plan formats.
d. Speed/Time Profile	220 KTS 1:10 ETE;	Current formats include cruising true airspeed and estimated time en route (ETE); ATC uses this information primarily to estimate arrival at the final approach fix in the event of lost communications in a non-radar environment. It could also be used to estimate the times at which the aircraft will be transitting various sectors to predict ATC sector loading. Although future flight planning and navigation capabilities could describe a speed profile in much more detail, its value in the strategic agreement process has not been established.

TABLE C-1
(Continued)

Information	Examples	Comments/Usage
3. Alternates	Takeoff: BWI Destination: ISP	Designation of alternate airports is required under certain weather conditions. If radio communications are lost and flight to the destination cannot be completed as planned, the flight is expected to proceed to the appropriate alternate. As long as radio communications can be maintained, the flight may negotiate other courses of action with the ATC system.
4. Search and Rescue (SAR) Data	Fuel on board; Persons on board; Pilot name/address; Color of aircraft; Remarks.	It is usually convenient to collect these data at the time the flight plan is submitted, even though the ATC system makes no immediate use of them.

TABLE C-1
(Continued)

1b. Information to Establish Initial Agreements--ATC-Issued Clearances

Information	Examples	Comments/Usage
1. Aircraft Identification	N8086W, TW880, Pacer 62	
2. Clearance Limit	CLEARED TO (airport)*. CLEARED TO (fix). CLEARED THROUGH (airport) TO (airport). * Note: Parentheses designate variables which are assigned appropriate names or values to address the situation.	The clearance limit specifies the extent to which the strategic agreement is effective. The aircraft is most often cleared to the destination airport, although in some cases it may be cleared only part of the way. In these cases, the controller will append Expect Further Clearance instructions, which specify how the flight is to be conducted in the event of lost communications.
3. Route of Flight		
a. Departure Routing	ON DEPARTURE... FLY RUNWAY HEADING TURN L/R DIRECT (fix) FLY (SID name) DEPARTURE	The ATC-issued clearance frequently includes tactical instructions such as these to specify how the aircraft should transition to the en route portion of the flight.
b. General Routing	THEN... AS FILED VIA VICTOR (airway number) VIA J (Jet airway number)	There are many possible ways to describe flight plan routings in the ATC system which are not listed here. The most commonly applied method involves linking

TABLE C-1
(Continued)

Information	Examples	Comments/Usage
		together appropriate segments of the VICTOR and JET airway systems. Others include the specification of the end fixes for direct route segments, or the specification of a fix and bearing.
4. Altitude Profile	(for a comprehensive list of possible messages, see Table C-2 under "Vertical Control").	Altitude instructions in the ATC-issued clearances are similar in format to those used in tactical messages. The main difference between altitude instructions in the strategic and tactical realms is the period of applicability. The altitude instructions in the strategic messages are generally applicable for longer periods of time in that they specify altitudes to be maintained over the duration of the flight. Tactical altitude messages, on the other hand, are issued to address a short-term condition as the aircraft maneuvers into or out of the terminal area.

TABLE C-1
(Continued)

Information	Examples	Comments/Usage
5. Holding Instructions	(for a list of possible holding messages, see Table C-2 under "Speed/Time/Delay Control").	Holding instructions are provided only when the flight cannot be cleared through to the destination, and they specify actions to be taken in the event the clearance limit is reached and communications are lost.

TABLE C-1
(Concluded)

2. Information to Amend Established Agreements

General comments: Amendments to established strategic agreements can be initiated by either the pilot or controller by specifying those parts of the agreement to be changed. The types of amendments most commonly observed in the current ATC system are changes in the clearance limit (when the pilot chooses to change destination), changes in the route, and changes in altitude. Rather than listing all possible amendments, a few of the more popular air-initiated amendment requests are provided below.

REQUEST DIRECT (destination airport).

REQUEST DIRECT (fix) {THEN FLIGHT PLAN ROUTE}.*

REQUEST HEADING FOR (fix) AND DIRECT WHEN ABLE {THEN FLIGHT PLAN ROUTE}.

REQUEST REVISED ROUTING AS FOLLOWS (routing amendment).

REQUEST (altitude) AS A FINAL ALTITUDE.

* Note: Message segments enclosed in braces { } denote an optional part of the message which may be retained or omitted to address the situation.

C.2 Tactical Messages

Current and postulated tactical messages are summarized in Table C-2. The review of references 19, 20, and 21 revealed several instances where the same message, or very similar messages, were used to address very different ATC situations. For example, a heading instruction could be issued to an aircraft to provide horizontal separation from other traffic, or to supplement the aircraft's navigation from point to point. Rather than list all of these possible variations of a tactical message (which would result in a voluminous and cumbersome catalog), the opportunity was taken where possible to combine these messages on the basis of the ultimate intended control action or response. As a result, several of the messages in Table C-2 are not a verbatim transcript as contained in References 19, 20, and 21, but are representative of messages used to effect a desired control action.

It should also be noted that "modifiers" are frequently included in tactical messages to tailor the instruction to the given situation. In issuing a climb instruction to an aircraft, for example, the controller may say "climb at best rate to FL240," or "climb and maintain FL350 best rate through FL290." In these examples, the controller is not only specifying a change in altitude but also how that change needs to be accomplished. In addition, the timing of the action on the part of the pilot can be changed with modifiers inserted in the message. In the absence of any other indication from the controller, the pilot is expected to initiate control action with reasonable promptness after acknowledging receipt of the instruction. However, the controller may relax this requirement by including phrases such as "at pilot's discretion," "when practical," or "when able"; or he may underscore the need for prompt, unquestioned compliance by including the word "immediate." For brevity, separate listing of these variations of the basic messages are not included in Table C-2, but it should be noted that most of the control messages in Table C-2 can be modified by including such phrases.

Finally, two or more messages are frequently "chained" together in a single transmission to indicate a sequence of control actions. The controller may imply that both control actions are to be performed simultaneously by saying, for example, "Descend and maintain two thousand feet, and turn left to a heading of three-six-zero," in which case the pilot is expected to initiate a descending left turn. The controller could otherwise assign a priority for multiple tactical instructions if simultaneous performance of the instructions would be difficult for the pilot or would not address the traffic situation. Such might be the case when combining an instruction to descend to a lower altitude with an instruction to reduce speed. The controller clarifies priorities by saying which action the pilot should perform first (e.g., "descend and maintain seven thousand, then reduce speed to two-one-zero knots"). Again, for the sake of clarity, Table C-2 does not list separately the many different ways in which tactical instructions could be combined, but it should be remembered that a wide variety of situations can be addressed through the uses of combined instructions and modifying phrases.

In Table C-2, the following symbols are used:

( ) Parentheses represent a variable part of the message which can be assigned a name or a numerical value, as appropriate, to met a given situation

{ } Braces surround those parts of a message which are optional

[ ] Brackets surround choices from which one (or more) selections are made to complete a message

TABLE C-2
TACTICAL MESSAGES

1. Horizontal Control - Heading-based Instructions

General comments: The first heading instruction which takes the aircraft off the route it was navigating is accompanied by the reason or intent for the instruction according to the following format:

heading instruction + "VECTORS" + reason/intent

Subsequent heading instructions do not include the reason or intent as long as it has not changed. The provision of reason or intent enables the pilot to plan an initial course of action in the rare event that radio communications are lost.

FLY PRESENT HEADING TURN L/R HEADING (degrees) TURN (degrees) L/R DEPART (fix) HEADING (degrees)	VECTORS	FOR TRAFFIC FOR SPACING FOR CLIMB/DESCENT FOR (procedure, e.g. "ILS 19L") TO (fix) TO INTERCEPT (route) AROUND (unusable airspace or weather)

FLY HEADING (degrees) UNTIL RECEIVING (navaid) THEN PROCEED DIRECT.

FLY RUNWAY HEADING.

AFTER REACHING (altitude) TURN L/R HEADING (degrees).

TABLE C-2
(Continued)

2. <u>Horizontal Control - Track-based Instruction</u>

General comments: Aircraft having advanced navigation capability can define and follow randomly-chosen tracks over the ground by automatically compensating for wind drift. ATC could make use of this capability by issuing track-based horizontal instructions to appropriately-equipped aircraft. This family of postulated messages follows the general form:

track instruction + reason/intent

As for heading-based commands, track instructions would initially include reason/intent; subsequent instructions would not include reason or intent if it has not changed.

FLY PRESENT TRACK TURN L/R TRACK (degrees) CHANGE TRACK (degrees) L/R DEPART (fix) TRACK (degrees)	FOR TRAFFIC FOR SPACING FOR CLIMB/DESCENT FOR (procedure, e.g., "ILS 19L") TO (fix) TO INTERCEPT (route) AROUND (unusable airspace, weather)

AFTER REACHING (altitude) TURN L/R TRACK (degrees).

TABLE C-2
(Continued)

3. <u>Horizontal Control - Airborne Navigation-based Instructions</u>

General comments: These instructions are based on the aircraft's ability to define and follow a course with respect to a navigation facility or fix.

PROCEED DIRECT (fix).

PROCEED TO (fix 1 or route 1) VIA (fix 2 or route 2).

(position with respect to course or fix) RESUME OWN NAVIGATION.

Note: The above instruction is usually issued when the intent of earlier horizontal instructions has been achieved, and the aircraft is expected to return to and follow the route specified in the latest ATC clearance.

RESUME (procedure, e.g., a SID or STAR) {COMPLY WITH RESTRICTIONS}.

INTERCEPT (route) AND PROCEED (direction).

FLY (miles) L/R PARALLEL OFFSET FROM (route).

Note: The above instruction is based on a postulated airborne capability to define/follow parallel offsets.

TURN L/R TO REJOIN (route) $\begin{bmatrix} \text{WHEN ABLE} \\ \text{AFTER (fix)} \end{bmatrix}$

TABLE C-2
(Continued)

4. Vertical Control

General comments: The term "altitude" in the following instruction may be used with respect to Mean Sea Level or with respect to a pressure datum of 29.92 in. hg. (in which case it is called a Flight Level).

MAINTAIN (altitude).

MAINTAIN BETWEEN (altitude 1) AND (altitude 2).

CRUISE (altitude).

Note: A "cruise" instruction authorizes the flight to be conducted at any altitude from the minimum IFR altitude up to and including the altitude specified in the cruise instruction. The pilot may change altitude within the limits at his discretion. However, once he starts a descent and reports leaving an altitude, he may not return to that altitude without ATC authorization to do so.

$$\left[\begin{array}{l}\text{CLIMB}\\ \text{DESCEND}\end{array}\right] \quad \text{AND MAINTAIN (altitude)} \quad \left\{\begin{array}{l}\text{AT PILOT DISCRETION}\\ \text{AT (time)}\\ \text{AFTER PASSING (fix)}\\ \text{WHEN ESTABLISHED ON (route)}\end{array}\right\}$$

Note 1: Unless PILOT DISCRETION is granted, the pilot is expected to initiate climb or descent promptly upon acknowledging the instruction or reaching the specified condition (time, fix, or route). Climb or descent must be conducted at no less than 500 feet per minute unless a lower rate is requested and granted. (Exceptions to this are temporary level-offs for speed reductions at 10,000 ft MSL and when entering an airport traffic area). The clause "PILOT DISCRETION" means the pilot may start the climb or descent whenever he chooses, and may use whatever rate of change he chooses.

TABLE C-2
(Continued)

Note 2: Vertical instructions may be "chained" together to specify multiple-step instructions in a single transmission. For example, a flight could be instructed as follows:

"DESCEND (now) AND MAINTAIN FL290 THEN DESCEND AND MAINTAIN FL240 AT PILOT'S DISCRETION."

$$\begin{bmatrix} \text{CLIMB} \\ \text{DESCEND} \end{bmatrix} \quad \text{TO REACH (altitude) BY} \quad \begin{bmatrix} \text{(time)} \\ \text{(fix)} \\ \text{AFTER PASSING (fix)} \\ \text{WHEN ESTABLISHED ON (route)} \end{bmatrix}$$

$$\text{CROSS (fix)} \begin{bmatrix} \text{AT} \\ \text{AT OR ABOVE} \\ \text{AT OR BELOW} \end{bmatrix} \text{(altitude).}$$

CROSS (fix) BETWEEN (altitude 1) AND (altitude 2).

MAINTAIN (altitude) UNTIL ESTABLISHED ON (course/route).

Note: This instruction is usually followed by an approach clearance which procedurally specifies subsequent authorized altitudes.

TABLE C-2
(Continued)

5. Speed/Time/Delay Control - Speed-based Instructions

General comments: In the following instructions, the term "speed" may refer to indicated speed through the airmass in knots or Mach number (Mach number is usually used above FL290). Regardless of which metric is used, the use of speeds with respect to the airmass facilitates the type of separation ATC is trying to achieve in using speed-based instructions. Although it might be possible in the future to issue groundspeed commands to appropriately-equipped aircraft, the advantages of doing so are not apparent.

MAINTAIN (speed).

MAINTAIN AT LEAST (speed).

DO NOT EXCEED (speed).

$\begin{bmatrix} \text{INCREASE} \\ \text{DECREASE} \end{bmatrix}$ SPEED $\begin{bmatrix} \text{BY} \\ \text{TO} \end{bmatrix}$ (number).

CROSS (fix) AT (speed).

RESUME NORMAL SPEED.

TABLE C-2
(Continued)

6. <u>Speed/Time/Delay Control - Time-based Instructions</u>

General comments: Time-based instructions form the basis for many advanced ATC concepts, but they require an advanced airborne navigation capability. The two forms of time-based instructions below are used in limited circumstances in the current ATC environment when the pilot can readily estimate and plan arrival times at assigned fixes (such as when leaving a holding pattern). With an advanced navigation capability, however, they could be applied in more situations.

CROSS (fix) AT [(time) / OR BEFORE (time) / OR LATER THAN (time)].

CROSS (fix) BETWEEN (time 1) AND (time 2).

7. <u>Speed/Time/Delay Control - Holding Instructions</u>

General comments: Holding instructions are issued when it is no longer possible to achieve desired spacing with speed commands alone. Initial holding instructions will always be accompanied by an Expect Further Clearance (EFC) or Expect Approach Clearance (EAC) time, which becomes operative in the event radio communications are interrupted. Because EFCs and EACs are conditionally operative, they are included in the Non-control Information category of Table C-3.

PROCEED TO (fix) AND HOLD (direction) AS PUBLISHED.

HOLD (direction) OF (fix) ON [(radial) / (course) / (bearing) / (airway) / (route)] [(number of minutes) / (number of miles) LEGS L/R TURNS].

TABLE C-2
(Continued)

8. Procedure-based Instructions - IFR Terminal Area Operations

General comments: The following procedure-based instructions are commonly issued to airborne IFR aircraft as they depart or arrive at the terminal area. Procedure-based instructions, it should be recalled, specify the aircraft's speed, altitude, and course according to an agreed-to procedure, such as an instrument approach procedure (IAP), standard instrument departure (SID), or standard terminal arrival route (STAR). These instructions are frequently supplemented by additional horizontal, vertical, or speed instructions as required by ATC.

CLEARED FOR APPROACH.

CLEARED FOR (type) APPROACH RUNWAY (number) {CIRCLE TO LAND RUNWAY (number)}.

CLEARED FOR STRAIGHT-IN (type) APPROACH RUNWAY (number) {CIRCLE TO LAND RUNWAY (number)}.

CLEARED FOR CONTACT APPROACH.

CLEARED FOR {procedure name} VISUAL APPROACH.

{MAINTAIN VISUAL SEPARATION FROM (aircraft) LANDING (runway)} CLEARED FOR VISUAL APPROACH TO (runway).

(horizontal, vertical instruction) TO JOIN (STAR name) ARRIVAL {(name) TRANSITION}.

(horizontal, vertical instruction) TO JOINT (SID name) DEPARTURE {(name) TRANSITION}.

TABLE C-2
(Continued)

9. Communications/Surveillance Instructions

CONTACT (facility) {ON (frequency)} {IF UNABLE, RETURN THIS FREQUENCY}.

CONTACT (facility) ON (frequency) AT (fix).

MONITOR (facility) ON (frequency) AND CONTACT AT (fix).

CHANGE TO ADVISORY FREQUENCY.

IDENT.

SQUAWK (code) [AND IDENT / AND ALTITUDE].

SQUAWK ALTITUDE.

STOP ALTITUDE SQUAWK.

RECYCLE TRANSPONDER SQUAWK (code).

CHECK MODE-C, ALTIMETER (setting).

Note: Non-transponder aircraft may be vectored for radar identification purposes, in which case the aircraft will be issued a heading, or series of headings, and advised that the headings are "for radar identification."

TABLE C-2
(Concluded)

10. Traffic and Urgent Advisories

TRAFFIC (clock position, distance) (direction)-BOUND {(altitude) {UNVERIFIED}}, {(type a/c)}, {(other a/c intentions & information)}, {REPORT IN SIGHT}.

TRAFFIC REPORTED (position), (altitude), (direction)-BOUND, {(other a/c intention)}.

WIND SHEAR ALERT (description).

LOW ALTITUDE ALERT, CHECK ALTITUDE, (geographic area) ALTIMETER IS (setting).

Note: In addition to the advisories mentioned above, additional safety-of-flight advisories have been proposed for d/l transmission with the implementation of advanced ATC and weather detection technologies. These range from real-time detection and dissemination of hazardous weather such as microbursts and downbursts to ground-based detection and warning of proximate air traffic. All of these applications would fall into this category of traffic and urgent advisories. However, detailed messages formats cannot be postulated until the type of information that would be issued in such advisories is better established.

TABLE C-2
(Continued)

11. Instructions for Local Operations

General comments: The following instructions are used to control VFR and IFR aircraft on the active runway or in the local traffic pattern. They may occasionally be supplemented by other tactical instructions.

CLEARED FOR {IMMEDIATE} TAKEOFF {[(traffic) / OR TAXI OFF RUNWAY / OR HOLD SHORT (traffic)]}

CANCEL TAKEOFF CLEARANCE (reason).

CLEARED [TO LAND / FOR TOUCH AND GO / FOR OPTION / FOR STOP AND GO / FOR LOW APPROACH] {RUNWAY (number)}{[NOT IN SIGHT / traffic advisory]}

GO AROUND.

CIRCLE THE AIRPORT.

FOLLOW (traffic) {LANDING RUNWAY (number)}.

AFTER COMPLETING (operation) [TURN L/R HEADING (degrees) / CLIMB AND MAINTAIN (altitude) / FLY RUNWAY HEADING].

TABLE C-2
(Continued)

CLEARED FOR TAKEOFF FROM (position).

HOLD $\begin{bmatrix}\text{PRESENT POSITION}\\ \text{(other position)}\end{bmatrix}$ FOR WAKE TURBULENCE.

MAKE $\begin{bmatrix}\text{LEFT}\\ \text{RIGHT}\end{bmatrix}$ CLOSED TRAFFIC.

CLEARED FOR LOW APPROACH AT OR ABOVE (altitude).

MAKE APPROACH $\begin{bmatrix}\text{STRAIGHT-IN}\\ \text{CIRCLING}\\ \text{LEFT/RIGHT TURN}\end{bmatrix}$ TO RUNWAY (number).

EXTEND DOWNWIND

MAKE SHORT APPROACH TO RUNWAY (number).

CIRCLE THE AIRPORT.

MAKE L/R $\begin{bmatrix}\text{THREE-SIXTY}\\ \text{TWO-SEVENTY}\\ \text{ONE-EIGHTY}\end{bmatrix}$.

GO AROUND.

(a/c ident) NUMBER (landing sequence number) {FOLLOW (traffic) LANDING RUNWAY (number)}.

TABLE C-2
(Continued)

PROCEED AS REQUESTED.

$$\text{REPORT}\begin{bmatrix}\text{RUNWAY}\\ \text{AIRPORT}\\ \text{APPROACH/RUNWAY LIGHTS}\end{bmatrix}\text{IN SIGHT.}$$

$$\text{ON MISSED APPROACH FLY}\begin{bmatrix}\text{PUBLISHED}\\ \text{(specified)}\end{bmatrix}\text{PROCEDURE.}$$

TOWER CLEARANCE CANCELLED.

$$\text{CLEARED}\begin{bmatrix}\text{TO ENTER}\\ \text{OUT OF}\\ \text{THROUGH}\end{bmatrix}\text{CONTROL ZONE \{(direction) OF (name) AIRPORT \{VIA (routing)\}\}.}$$

$$\text{MAINTAIN SPECIAL VFR CONDITIONS}\begin{bmatrix}\text{WHILE IN CONTROL ZONE}\\ \text{AT OR BELOW (altitude)}\end{bmatrix}.$$

TABLE C-2
(Continued)

12. <u>Instructions for Ground Operations</u>

General comments: The complex nature of the runway and taxiway geometries at many airports make compilation of an exhaustive list of ground operations instructions very difficult. Included below are those instructions frequently used during the course of normal ground operations.

CLEARED TO $\begin{bmatrix}\text{PUSHBACK} \\ \text{START ENGINES}\end{bmatrix}$, {ADVISE READY TO TAXI}.

$\begin{bmatrix}\text{PUSHBACK} \\ \text{START ENGINES}\end{bmatrix}$ {AT PILOT'S DISCRETION}.

TAXI TO RUNWAY (number).

TAXI VIA (route) TO RUNWAY (number).

ACTIVE RUNWAY IS (number).

TURN L/R {ON THE $\begin{bmatrix}\text{TAXIWAY} \\ \text{RUNWAY}\end{bmatrix}$ YOU ARE APPROACHING}.

$\begin{bmatrix}\text{HOLD SHORT OF} \\ \text{CROSS}\end{bmatrix}$ $\begin{bmatrix}\text{RUNWAY (number)} \\ \text{TAXIWAY (name)}\end{bmatrix}$.

TAXI TO $\begin{bmatrix}\text{RAMP} \\ \text{GATE}\end{bmatrix}$, {VIA (route)}.

C.3 Non-Control Information Messages

Table C-3 lists those non-control information messages for which specified, consistent formats are use in the current ATC system. As described in Section 2, non-control information messages fall into these major subcategories; namely, 1) weather-related observations and forecasts, 2) reports on the status of facilities and equipment, and 3) routine reports such as position reports and estimated time of arrival, etc. In most cases, a fairly rigid format has been specified in References 19, 20, or 21, for the packaging of information in these messages. However, some of the weather products now provided via r/t are primarily in a free-form text format. Table C-3 mentions these messages in the appropriate subcategory but does not specify a format, as a single format does not exist.

It should be noted that for weather messages, in particular, future exchanges of information on d/l may be performed with graphics instead of text. Cathode ray tube (CRT) displays in the cockpit readily lend themselves to the portraying of graphic information obtained on d/l. It is technically feasible, and in some cases operationally desirable, to convert textual information to be portrayal graphically. In addition, many graphic weather materials such as charts (for example prognostic charts of radar summaries) could be uplinked as well for portrayed in the cockpit. Even though these are possible applications of d/l, they are not included in Table C-3, as much more needs to be specified in terms of the weather products themselves, and the formats to be used to exchange the information.

TABLE C-3
NON-CONTROL INFORMATION MESSAGES

1. Weather Messages

General comments: Of the various textual weather products now provided over r/t, some are issued according to fairly standardized formats (such as hourly surface observations), while others are issued using free-form text. Examples of the latter include terminal forecasts, area forecasts, pilot reports, Airmets, Sigmets, and Convective Sigmets. Although contractions and abbreviations have been specified for words and phrases commonly used in these weather products, the use of the free-format construction of actual messages makes it difficult to list all possibilities in this table. It should also be noted that research is underway to provide a standard structure for these weather products to make them easier to encode and disseminate digitally.

WIND (direction, velocity) {GUSTS (velocity)} {DIRECTION (number) VARIABLE (number)}.

(facility) ALTIMETER (number).

ATIS INFORMATION (letter, (time), WEATHER (sky condition), (visibility and obscuration), (temperature), (dewpoint), (wind), (altimeter), (landing and departure instruction), {special instructions and notices}.

SURFACE OBSERVATION (location), (time), WEATHER (sky condition), (visibility and obscuration), (temperature), (dewpoint), (wind), (altimeter), (remarks).

(location) WINDS AT (altitude) (direction and velocity) {temperature}.

Note: This format is used to transmit winds aloft data. Several of these messages are frequently chained together to provide winds aloft information at a given location for several different altitudes. The format and type of information in winds aloft messages may make it desirable to be portrayed in graphic terms (such as a superimposed vector) in future cockpits.

CHECK DENSITY ALTITUDE.

TABLE C-3
(Continued)

2. Equipment and Facilities Status

BRAKING ACTION $\begin{bmatrix}\text{POOR}\\ \text{FAIR}\\ \text{GOOD}\end{bmatrix}$, REPORTED BY $\begin{bmatrix}\text{(a/c type)}\\ \text{VEHICLE}\end{bmatrix}$.

BRAKING ACTION ADVISORIES IN EFFECT.

RUNWAY (number) $\begin{bmatrix}\text{CLOSED}\\ \text{UNSAFE}\end{bmatrix}$ {OPERATION AT OWN RISK}.

LANDING WILL BE $\begin{bmatrix}\text{TOWARD}\\ \text{OVER}\end{bmatrix}$ RAISED BARRIER/CABLE. {BARRIER/CABLE INDICATES $\begin{bmatrix}\text{UP}\\ \text{DOWN}\end{bmatrix}$}.

$\begin{bmatrix}\text{LOCALIZER}\\ \text{GLIDE SLOPE}\end{bmatrix}$ SIGNAL IS NOT $\begin{bmatrix}\text{MONITORED}\\ \text{PROTECTED}\end{bmatrix}$.

PRIMARY RADAR OUT OF SERVICE

Note: In addition to the examples mentioned above, the FAA has an extensive collection and dissemination system for the operational condition of various elements of the National Airspace System. Notices to Airmen (NOTAMs) describe conditions of equipment and facilities which could affect flight operations, and are issued in special and routine publications, via teletype, and various other means. Because NOTAMs are issued to describe a wide variety of conditions, it is not possible to list all of them in this table.

TABLE C-3
(Continued)

3. <u>Routine Reports</u>

REPORT PASSING (fix).

REPORT $\begin{bmatrix} \text{INTERCEPTING} \\ \text{CROSSING} \\ \text{DEPARTING} \end{bmatrix}$ (route).

REPORT (segment of approach procedure).

REPORT POSITION.

Note: Position reports are usually requested in a non-radar environment or to facilitate initial radar identification. The recommended position report format is
(aircraft identifier) (position) (time) (altitude) {(route) (next reporting point) (estimated time of arrival)}

(aircraft identifier) ENTERING HOLD AT (fix) {AT (time)} (altitude).

EXPECT $\begin{bmatrix} \text{CLIMB} \\ \text{DESCENT} \end{bmatrix}$ CLEARANCE $\begin{bmatrix} \text{IN (minutes)} \\ \text{IN (miles)} \\ \text{AT (fix)} \end{bmatrix}$.

EXPECT (altitude) AT $\begin{bmatrix} \text{(fix)} \\ \text{(time)} \end{bmatrix}$.

EXPECT TO RESUME (route) AT $\begin{bmatrix} \text{(fix)} \\ \text{(time)} \end{bmatrix}$.

EXPECT FURTHER CLEARANCE AT $\begin{bmatrix} \text{(fix)} \\ \text{(time)} \end{bmatrix}$.

EXPECT APPROACH CLEARANCE AT (time).

TABLE C-3
(Concluded)

ANTICIPATE ADDITIONAL (time) $\begin{bmatrix}\text{EN ROUTE}\\ \text{TERMINAL}\end{bmatrix}$ DELAY.

EXPECT (number) MINUTES GATE HOLD.

EXPECT ENGINE START AT (time).

RADAR CONTACT (position).

RADAR CONTACT LOST (position).

RADAR SERVICES TERMINATED.

VERIFY AT (altitude).

VERIFY ASSIGNED ALTITUDE IS (altitude)

VERIFY ALTITUDE AND ALTIMETER SETTING.

REPORT $\begin{bmatrix}\text{LEAVING}\\ \text{REACHING}\end{bmatrix}$ (altitude).

REPORT $\begin{bmatrix}\text{LEAVING}\\ \text{REACHING}\end{bmatrix}$ $\begin{bmatrix}\text{ALL}\\ \text{ODD}\\ \text{EVEN}\end{bmatrix}$ ALTITUDES.

SAY $\begin{bmatrix}\text{ALTITUDE}\\ \text{AIRSPEED}\\ \text{MACH NUMBER}\\ \text{HEADING}\end{bmatrix}$

EXPECT $\begin{vmatrix}\text{type}\\ \text{VISUAL}\end{vmatrix}$ APPROACH {RADAR VECTORS TO FINAL APPROACH COURSE}.

EXPECT VECTOR ACROSS (course) FOR (reason).

APPENDIX D

REFERENCES

1. Aeronautical Radio, Inc. (March 1982), ARINC Characteristic 597-3 ARINC Communications Addressing and Reporting System (ACARS), Annapolis, MD.

2. Radio Technical Commission for Aeronautics (March 1983), Minimum Operational Performance Standards For Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment, RTCA/DO-181.

3. "Air Traffic Control Radar Beacon System and Mode S Transponder Requirements in the National Airspace System" (September 1985), The Federal Register, Volume 50, No. 180, Washington, D. C.

4. Signore, T. L. (May 1985), Mode S Data Link System Requirements to Support Initial Services, Coordination Draft, WP-84W41, McLean, VA: The MITRE Corporation.

5. Diehl, J. M. (August 1984), Analysis of NAS Plan Required Data Link Services Using Mode S, Coordination Draft, WP-84W78, McLean, VA: The MITRE Corporation.

6. Diehl, J. M. (October 1986), Mode S Data Link Service Development Plan, WP-86W441, McLean, VA: The MITRE Corporation.

7. Anderson, S., et al. (October 1985), Aeronautical Satellite Data Link Concept, Design, and Flight Test Results, MP-85W102, McLean, VA: The MITRE Corporation.

8. International Civil Aviation Organization (April 1985), Special Committee on Future Air Navigation Systems - Report of the Second Meeting, Montreal, Canada.

9. Schoppe, W. J. (December 1984), "The Navy's Tactical Data Network," Proceedings of the Sixth Digital Aeronics Systems Conference, Baltimore, MD: Naval Air Development Center, Warminister, PA.

10. Parker, James F., Jr.; and Duffy, Jack W. (1982). "A Flight Investigation of Simulated Data-Link Communications During Single-Pilot IRF Flight. Volume II - Flight Evaluations." NASA Langley Research Center. NASA CR-3653.

11. Ackermann, R. and H. Radke (November 1982), Evaluation of an Airborne Terminal for a Digital Data Link in Aviation, DFVLR, Braunschweig, Federal Republic of Germany.

12. Wisleder, R. W., et al. (1975), "An Experimental Evaluation of Various Electronic Cockpit Displays for Air/Ground Data Link Communications," AGARD Conference Proceedings No. 167 on Electronic Airborne Displays.

13. Companion, M. A., and G. A. Sexton (October 25-28, 1982), "The Role of Pilots and Automation in Future Transport Flight Stations," Behavioral Objectives in Aviation Automated Systems Symposium: Proceedings of the Aerospace Congress and Exposition, Anaheim, CA: Lockheed-Georgia Co.

14. Ganneti, J. R. (October 25-28, 1982), "The Pilot and Flight Management System," Behavioral Objectives in Aviation Automated Systems Symposium: Proceedings of the Aerospace Congress and Exposition, Anaheim, CA: Boeing Co., Seattle, WA.

15. Miles, W. L., et al. (October 25-28, 1982), "Advanced Commercial Cockpit Concepts," Behavioral Objectives in Aviation Automated Systems Symposium: Proceedings of the Aerospace Congress and Exposition, Anaheim, CA: Douglas Aircraft Co., Long Beach, CA.

16. Rucker, R. A. (October 1982) Digital Avionics, Air-Ground Data Link and the Evolving Air Traffic Control System, MP-82W28, McLean, VA: The MITRE Corporation.

17. Rucker, R. A. (December 6, 1983), Some Postulated Digital Uplink Message Types for ATC Clearance and Control, Letter to Radio Technical Commission for Aeronautics-Special Committee 142, McLean, VA: The MITRE Corporation.

18. Tanenbaum, A. S. (December 1981), "Network Protocols," Computing Surveys, Volume 13, Number 4.

19. Federal Aviation Administration (October 1984), The Handbook of Air Traffic Control, FAA Order 7110, 65D, Washington, D. C.: U. S. Government Printing Office.

20. Federal Aviation Administration (April 1983), Flight Services Handbook, FAA Order 7110.10G, Washington, D. C.: U. S. Government Printing Office.

21. Federal Aviation Administration (January 1986), Airman's Information Manual, Basic Flight Information and ATC Procedures, Washington, D. C.: U. S. Government Printing Office.

22. Berry, T. P. (1983), Cockpit Data Management Requirements for Current Technology Aircraft, 1378-03-8-3150, Annapolis, MD: ARINC.

23. National Aeronautics and Space Administration - Aviation Safety and Reporting System Office, (September 1981) Information Transfer Between Air Traffic Control and Aircraft: Communication Problems in Flight Operations, NASA-ASRS, Moffett Field, CA.

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16. Abstract

The planned modernization of the U.S. National Airspace System (NAS) includes the development and use of digital data link as a means to exchange information between aircraft and ground-based facilities. This report presents an operationally-oriented concept on how data link could be used for applications related directly to air traffic control. The specific goal of this research effort is to establish the role that data link could play in the air-ground communications. Due regard is given to the unique characteristics of data link and voice communications, current principles of air traffic control, operational procedures, human factors/man-machine interfaces, and the integration of data link with other air and ground systems. The resulting concept is illustrated in the form of a "paper-and-pencil" simulation in which data link and voice communications during the course of a hypothetical flight are described.

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