REPORT NO. DOT-TSC-FAA-71-20

DISPERSED PROCESSING FOR ATC

G. G. PAUL, R. M. SNOW
TRANSPORTATION SYSTEMS CENTER
55 BROADWAY
CAMBRIDGE. MA. 02142

JUNE 1971
TECHNICAL REPORT

Prepared for
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D. C. 20546

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. DOT-TSC-FAA-71-20	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Dispersed Processing for ATC		5. Report Date June 30, 1971
		6. Performing Organization Code TCC
7. Author(s) Grant G. Paul & Robert M. Snow		8. Performing Organization Report No.
9. Performing Organization Name and Address DOT/Transportation Systems Center 55 Broadway Cambridge, MA 02142		10. Work Unit No. 71-FA-0
		11. Contract or Grant No. FA-03-2
12. Sponsoring Agency Name and Address Federal Aviation Agency 800 Independence Ave., S.W. Washington, D.C.		13. Type of Report and Period Covered Interim Technical Report
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An analysis has been made of the potentialities and problems involved in assigning some computer processing and control functions to the remote sites in an upgraded third generation air traffic control system. Interrogator sites offer the most fruitful opportunities for remote processing. The minimal remote processing configuration consists of extraction, compaction, and encoding of locally derived data. With concurrent remote tracking, additional tasks may be added, including roll call generation, data link management, ground communications management, and IPC service. Phased-array management is considered to be the function of a separate dedicated controller. Attention is directed to the need for an "orderwire" net to avoid problems of floating control

17. Key Words Dispersed Processing, Air Traffic Control, Remote Tracking, Data Link, Intermittent Positive Control, Discrete Addressing	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	16	

Form DOT F 1700.7 (8-69)

TABLE OF CONTENTS

1. INTRODUCTION

This Interim Report is based upon a preliminary study of the problems and potentialities inherent in performing some of the ATC processing functions at the remote sites. Two types of remote sites are considered in this connection: interrogator sites and skin radar sites. The most fruitful possibilities for remote processing are those associated with interrogator sites, for reasons which are discussed in Section 3.8.

Processing tasks appropriate to the various options for the upgraded third generation ATC system are summarized in Section 2. Based on this background, Section 3 treats the identification and selection of tasks that may be considered candidates for remote processing.

All major conclusions are summarized in Section 4. A tendency is noted toward processing assignments of two types: (1) the minimal assignment, for which remote processing consists only of extraction, compaction, and encoding of locally derived data, and (2) an expanded assignment which includes the many additional tasks that become possible if independent tracking operations are carried out at remote sites. Attention also is directed to the need for an ultra-reliable, very low data rate "orderwire" net to avoid problems of floating control. Finally, it is recommended that control of phased-array antennas should be considered as the function of a dedicated controller (to be developed as part of the phased-array system) rather than as a dispersed processing task.

Within the logical framework presented in this report, future work will be directed toward quantitative characterization of remote-processing schemes, leading to trade-off studies and recommendations of specific processing configurations.

2. PROCESSING TASKS ASSOCIATED WITH UPGRADING OPTIONS

The evolutionary growth from second-generation ATC a "manual system" to third generation ATC, sees the introduction of automated techniques to aid the traffic controller maintain proper separation and control of air traffic. Primary data acquisition is performed by the Air Traffic Control Radar Beacon System (ATCRBS) that supplies positional information, altitude, and identity of aircraft and is backed up by skin radar returns. Ground-air communications are accomplished by VHF voice.

In the process of upgrading the third generation ATC system, emphasis is placed on the following five areas:

1. Increased automation - As traffic density increases, the level of automation must also increase to improve overall system efficiency as well as to reduce the routine workload of the air controller. In this manner, the controller's capacity to handle traffic can be increased and he can realistically be responsible for more aircraft in his sector.
2. Improved beacon performance - The accuracy and overall operational effectiveness of the radar beacon system must be improved in order to meet future traffic requirements. This can be accomplished by re-siting and redesigning the beacon antenna as well as incorporating better interrogator management techniques.
3. Data Link - Increasing automation and high traffic densities require the use of more efficient communication techniques than VHF voice. The incorporation of a data link between control center and aircraft, using the radar beacon as a common data acquisition/data link system, is one alternative for providing separation messages to aircraft. These messages can be time-interleaved, discretely addressed, and range ordered to the desired aircraft via a new upgraded beacon. In this manner, the air traffic controller is relieved of the heavy communications burdens arising from expanded aircraft density.
4. IPC service - In high density airspace, it becomes advantageous to carry out processing at the control center to predict and resolve conflicts between controlled aircraft as well as between controlled and uncontrolled aircraft under ATC surveillance.

Evasive commands can be generated automatically by the ground computer and transmitted via data link to the aircraft for appropriate action.

5. Reliability - The strong requirement for high operational reliability of the ATC system becomes even more important with increasing automation and expanded traffic. Backup modes of operation must be utilized in case of failures, and the entire system must employ "fail-safe" and "fail-soft" techniques. It has been suggested that some form of dispersed processing will be desirable for high operational reliability.

Each of these five areas has a direct impact on the processing requirements for the proposed upgraded third generation ATC system. The processing tasks associated with the upgrading options are discussed in the following subsections.

2.1 Increased Automation

Increasing the level of automation at the Air Route Traffic Control Center (ARTCC) has an overall goal of reducing the air traffic controller's routine workload and placing him in an environment where he monitors and maintains executive control over the operational systems within his sector. In this environment, the air controller can realistically be responsible for more aircraft within his sector, as well as be able to devote more attention to special situations and emergencies.

Processing at the ARTCC includes maintaining a data file for each aircraft flying under center control. Filed flight plans, stored in computer memory, are periodically recalled and compared with tracking data obtained from the data acquisition sites and updated for each aircraft under ATC control. Route deviations are detected and corrected if necessary. In addition, route data are monitored for potential conflicts with other aircraft (both controlled and uncontrolled) flying in the area, and appropriate measures taken to resolve these conflicts. Normal separation and control are achieved by projecting flight paths and examining the resultant data for potential conflicts. The computer also meters the flow of air traffic and regulates this flow into the dense terminal areas.

For successful execution of the processing tasks at the control center, accurate tracking data must be available from both beacon and skin return radar. The beacon serves as the primary surveillance system for aircraft under ATC control, while the skin return radar serves as a backup system for detecting uncontrolled aircraft intrusions into positive controlled airspace and permits detection of aircraft whose transponders have failed. A second factor is the availability of backup modes of operation in case of system failures. System redundancy and dispersion of responsibilities should be such that in cases of severe equipment failures the ATC system still remains operational, with some gradual degradation allowed.

2.2 Improved Beacon Performance

The evolution of the present data acquisition network has developed into a successful operational system to meet the challenge of present air traffic control problems. Several changes in the radar beacon have been proposed to enable it to cope reliably with an expanded air traffic environment. Techniques for updating and improving beacon operation can be divided into two broad classifications. The first of these involves short-term modifications to the existing structure design in order to improve system performance. These improvements have little impact on the processing requirements of the system. Among some of the more significant improvements that have been proposed and/or are being implemented are Side Lobe Supression (SLS), Receiver Side Lobe Suppression (RSLS), defruiting, better interrogator management, and other techniques to increase the round reliability of the system. A significant addition to the present system has been altitude reporting (Mode C).

The second classification for updating ATCRBS operation involves long-term improvements, including evolutionary restructuring of the beacon network to fit the requirements of the upgraded third generation ATC system. One such improvement having a direct influence on the processing requirements involves the separation and relocation of the beacon antenna.

Co-location of the interrogator antenna with the skin-radar antenna is regarded as non-optimum for system performance. Mechanical and locational restrictions on the co-located interrogator antenna give rise to relatively wide beams (limiting both azimuth accuracy and target resolution capability) along with a significant susceptibility to lost and garbled replies caused by poor coverage, fruit, and multipath. Because of severe vertical lobing, the interrogators are often overpowered to assure interrogation on aircraft in the null areas. This causes additional problems with system round reliability and fruit. Separating and redesigning the beacon antenna is the first step in alleviating some of the problems of the present system. The mechanical redesign of the antenna for narrower beam widths coupled with monopulse reception techniques will increase azimuth accuracy and resolution. Shaping the vertical pattern of the antenna and better siting will minimize vertical lobing, thereby improving coverage and perhaps reducing the power requirements of the interrogator. Better siting may also require fewer interrogator locations to service a given area. A reduction of interrogator power coupled with a reduction of active interrogator sites will result in improved system round reliability as well as reduced fruit.

The incorporation of phased-array antennas in the radar beacon system appears likely (at least in the dense hub areas) in order to permit efficient handling of the high volume of air traffic. By using electronically steered beams, accuracy can be enhanced, and techniques for discrete addressing as well as for incorporating a high-speed data link can be facilitated. The phased-array antenna beam can be operated in either a scanning mode or an agile (beam-hopping) mode, as required, and would be compatible with both modified and unmodified beacon transponders.

2.3 Discrete Addressing and Data Link

As the density of air traffic increases, it becomes inefficient to rely too heavily upon voice communications between control center and aircraft. In view of the level of automation achieved at the control center, it becomes particularly advantageous to incorporate a data link between the computer at the ARTCC and the aircraft for the transmission of separation control messages. A useful processing task is the addition of coding for discrete addressing to allow each aircraft to accept only those messages addressed to it. With discrete addressing, a significant reduction of synchronous garble (which occurs when the density of aircraft exceeds the positional resolution of the radar beacon) can be realized. Other important processing tasks are the time-interleaving of messages to the aircraft, with standard mode 3A and C interrogations, and range ordering prevent garbling of replies.

Discrete addressing, range ordering,and data link are (in principle) possible with rotating interrogator antennas, but the message capacity would be limited by the relatively slow rotation period of the antenna. This limitation will be more severe for the larger interrogator antennas that are planned, even if back-to-back dishes are used. For high density airspace, it appears likely that phased-array interrogators will be used to handle the required message rates in these areas. Aside from increased accuracy, agile beam positioning can facilitate transmission (and reception) of messages. By beam-steering and range-odering, and with appropriate processing, message rates of several thousand 50-bit messages per second can be realized.

2.4 IPC Service

One important service of the ARTCC is Intermittent Positive Control(IPC), a part of its overall ground collision avoidance system. Positional data supplied by the ATCRBS along with data from the skin return radar are to be continually monitored and processed for potential conflicts. When a conflict is possible or imminent, evasive maneuvers will be computed and the appropriate commands generated by the ATC computer and automatically transmitted to the pilot via the data link.

IPC messages differ from ATC messages in that IPC messages contain fewer bits and occur less frequently than the normal ATC message. However, they carry a much higher priority along with a high reliability requirement. Once a data link is incorporated into the ATC system, conflict detection and IPC involve only straightforward processing tasks. However, questions of system control for IPC, particularly in failure modes, are rather complex and require careful study. Remote processing is of potential value here, in providing the flexibility of several options for coping with a variety of failure conditions. It should also be noted that the implementation of an IPC service may require the use of electronically steered beams at the interrogator site to overcome the comparatively long access time of rotating interrogators. This topic needs additional study.

2.5 Reliability

The significance of high reliability for the upgraded ATC system cannot be overstated. Aside from having backup equipment for fail-safe operation, the system must be capable of operating in case of catastrophic failure (such as an entire ATC center being out of commission), although some gradual degradation of system performance may be tolerated.

Failures can occur either at the remote sites, at the ATC centers, or in the communication links between ATC center and remote site. Failures can also occur in the communication links connecting ATC centers. Failures occurring at the remote sites may be compensated by using data from other interrogator sites which have overlapping coverage and/or by activating certain interrogators that operate on a stand-by basis. Skin return radar may also be used as a backup (although its primary use will be for the detection of aircraft intruded into positive-control airspace and the detection of aircraft with failed transponder units). Partial or complete failures occurring at an ATC center can be compensated by reassigning the processing functions and responsibilities, either to other ATC centers, or (for certain limited tasks) to remote sites equipped to perform processing. Communication failures can be compensated by incorporating redundancy in the communications channels and having an alternate routing capability for the desired information. Communications failures between the ATC center and remote site may be mitigated by using information from other interrogator sites having overlapping coverage.

System reliability requires that the ARTCC have managerial control over reassignment of processing tasks to other locations. "Floating control," whereby another site seizes control of some vital control function without explicit authorization by the control center, probably cannot be tolerated under any circumstances. The implication of this stricture on intersite communications is discussed in Section 3.4.

3. IDENTIFICATION OF CANDIDATE REMOTE PROCESSING TASKS

The concept of dispersed processing at the remote site adds flexibility to the ATC system in that by incorporating appropriate control transfer and backup capability, normal or near normal ATC operations can be continued in case of system failures. In addition, processed aircraft reply data rather than wideband unprocessed data can be sent to the control center, resulting in more efficient use of the communication channels with a consequent increase in communications reliability. Finally, the performance of routine processing tasks at the remote site alleviates the processing burden at the control center.

3.1 Roll Call Generation

A routine task to be considered for remote site processing is the establishment and generation of roll call interrogations. These interrogations can be range ordered from available tracking data and discretely addressed to the desired aircraft. The sequencing of the interrogations can be carried out by the computer at the remote site.

Roll call generation at remote sites is advantageous for several reasons. Communications from the ARTCC would be reduced, and the control center would be relieved of a routine processing task. In addition, data acquisition could still continue in the event of failures occurring either at the control center or in the communication link between the control center and the remote site. Data would also be preserved for startup by the control center or by an adjacent center. Current tracking information must be available if remote site roll call generation is to be realized practically.

3.2 Data Extraction and Compaction

With increasing air traffic density both the number of aircraft being interrogated from a particular interrogator and the frequency of these interrogations will increase. The resultant reply data transmitted from the aircraft become voluminous. Performing the required processing of reply data at the remote site rather than transmitting wideband information back to the control center for data reduction would significantly minimize the communications requirements between the ARTCC and the remote site. Thus the aircraft identity, altitude, range, and azimuth can be extracted at the remote site and transmitted to the control center in a more compact form, compatible with the input format of the central computer. In addition, the transformation of this positional information into ARTCC coordinates can be carried out at the interrogator site. For rotating interrogators, center-marking techniques, perhaps of an improved variety, can be performed at the remote site.

This type of data extraction and compaction at the remote site constitutes a task that is well suited to a small dedicated processor, and it is expected that it would be a minimum feature of any remote processing scheme as well as an evolutionary step toward more sophisticated configurations.

3.3 Data–Link Management

It has been suggested that data link messages be routed through the ATCRBS interrogators. This implies a set of processing tasks which can be performed advantageously at the interrogator sites. Messages received from the control center are error-checked, and corrections are made either by error-correction coding or repeat-transmission request. Identity and positional information are stripped from the message and checked with the tracking information available at the remote site. The remote processor then sets the proper timing for transmission of this message to the desired aircraft. After receipt, the aircraft acknowledges to the interrogator that the message has been properly received and validated (by error checking and perhaps by other tests performed in the aircraft). If an acknowledgement is not received, the interrogator should be programmed for automatic re-try and the entire message retransmitted to the aircraft. (Messages still not acknowledged might then be transmitted by another interrogator site, but this should be under center control rather than direct remote-to-remote request.) Confirmation of acknowledged messages, along with downlink information, are appropriately coded and sent to the ARTCC. In effect, the processing at the interrogator can be thought of as a buffer between the control center (where these messages originate) and the designated aircraft (destination), along with error checking, validation, and code conversion.

3.4 Ground Communications Management

It may prove advantageous to connect contiguous remote sites by communication links for several reasons:

a. to permit alternate routing of data and commands in the event of failure of one or more direct links;
b. for intercommunication on matters of mutual interest to two remote sites (such as handoff) or mutual backup in areas of overlapping coverage.

Other reasons may appear as a result of further study. If remote sites are directly interconnected, there will be significant processing tasks in communications management which can be performed advantageously by processors at remote sites. In addition, remote processors can be very useful in monitoring the quality of each communication link and in diagnosing and localizing faults.

The practicality of maintaining successful ATC operations, particularly in the face of severe system failures, is highly dependent on the reliability of the communications channels and networks interconnecting remote sites and control centers. Redundancy and alternate switching are required for these communications channels in order to have minimum "down time" due to failures in these links. When system failures occur, delegation of processing responsibility to the remote site must be made in an efficient manner. Two options exist for remote-site takeover under failure conditions:

1. Automatic takeover when the remote site senses failures in communication channels or failures occurring at control center,
2. Remote site takeover only upon command from the control center.

The first option permits automatic takeover even in situations where command communication is not possible. It does have the significant disadvantage that under certain classes of failures, the ARTCC may unnecessarily (and undesirably) yield control to the remote site that, except for maintenance personnel, is basically an unmanned site. This limitation might be accepted under some conditions, but a conservative approach to seizure of control is highly desirable. The conditions (if any) under which seizure of control by the remote site will be tolerated requires careful study.

The second option of remote takeover has the advantage that all control is accomplished at the ARTCC level unless the ARTCC, upon its own decision, decides to relinquish control to the remote site. However, it is restricted by the requirement for <u>some</u> communications between the control center and remote site.

The requirements for remote site to control center communications are relatively wideband. The command functions between the control center and remote site can be handled by an alternate, ultra-reliable (presumably wire) channel for transmission to the remote site. This command, or orderwire, channel has the distinct advantage that it supports relatively low data rates, well within the limits of voice grade lines. It is possible to achieve the required reliability for an orderwire net with minimal technical risks. This orderwire net permits the ARTCC to maintain command control over the remote site at all times. This can be accomplished either automatically (with human supervision) or manually under the traffic controller's authority. The orderwire net also can be used for switching control at the remote site and for reassigning processing and communications functions to other remote sites or even to adjacent control centers.

The impact of transmitting control information over separate channels will have to be studied in detail with particular emphasis on accurate reliability estimates of the orderwire line. There appears to be no reason why acceptable reliability of an orderwire net could not be readily achieved, although serious consideration will have to be given to physical hazards such as earthquakes and storms.

3.5 IPC Service

Detecting potential conflicts and calculating evasive maneuvers is a processing function which will normally be performed at the ATC center. Under normal circumstances, the remote processing tasks associated with IPC messages would be similars to those tasks being performed for data link messages. The importance and need for high reliability in intermittent positive control suggests additional remote processing capability in order to provide "dynamic backup" for conflict detection and IPC message generation normally performed at the control center.

One form which the suggested dynamic backup could take assumes that short-term conflict predictions and calculations of appropriate evasive maneuvers be performed in parallel, at the remote site as well as at the ARTCC. (This implies that the remote site is carrying on parallel tracking function based on self-derived data.) Whenever the remote site calculations reveal a conflict, the evasive maneuver is transmitted to the ARTCC for comparison with similar calculations made at the center. If a correlation does not exist, the central computer makes a rapid algorithmic determination of which course to follow (i.e., whether to transmit the IPC message originating at the control center or the IPC message originating at the remote site) based upon whatever fast diagnostic information may be available.

In cases of communications failures between the ARTCC and the remote site, sole IPC responsibility can be given to the remote site, but only upon command from the control center. This command would be given via the orderwire channel from the ARTCC. Thus the control center would maintain command control over the remote site in case of failures, although primary processing would be performed at the remote site.

3.6 Tracking

Many candidate processing assignments require that the remote site have direct access to current position of each aircraft within its purview. This can be accomplished by performing the short-term tracking computations at the remote site concurrently with the control center. In theory, it would be possible to avoid this concurrent tracking requirement by sending current positional data from the control center as it is needed. However, this flow of positional updates would place an unnecessary burden on the center-to-remote site communication links, with no advantage other than avoiding a straightforward numerical computation. A quantitative trade-off study (including reliability considerations) will be made of the relative merits of concurrent remote tracking versus transmission of central track data, but at this time it would appear that concurrent remote tracking is the better choice.

It is also conceivable that tracking could be performed only at the remote sites, thus relieving the control center of the task of short-term tracking computations. (Longer term tracking presumably would still be performed at the control center.) This suffers from the same disadvantage of burdening the communication channel in order to obtain a minor advantage. Pending detailed trade-off study, it still appears that concurrent remote tracking is the better choice.

Although it may be questioned whether concurrent tracking could be justified to support any one remote processing task, availability of tracking data opens the way to the remote performance of additional processing tasks. Thus, there is a natural tendency toward two types of remote-processing assignments:

a. Minimum assignment - only those tasks which can be performed without remote tracking.
b. Expanded assignment - including all or most all of the tasks which become possible with direct access to tracking data.

In summary, for remote-processing tasks which require updated positional information, tracking should be performed concurrently at the control center and at the remote site. Tracking at the control center is to be used for many ATC tasks including conflict detection for the ground collision avoidance systems. It would also be used in the preamble for ATC and IPC messages to provide the locational information (i.e., range and azimuth) for transmission to the desired aircraft. Tracking at the remote site is to be used in generating roll call for routine interrogations, checking message preambles from the control center, and remote-site conflict detection for IPC backup. An important advantage of tracking at the remote site is that it permits data acquisition and IPC service to continue in the event of failures occurring at the control center.

3.7 Phased–Array Management

The processor associated with the phased array sets the phase-shifting networks in order to electronically form and steer the antenna beam. The positional data for this processing task are based on tracking information either obtained at the remote site or transmitted from the control center as a message preamble. The phased-array control processor should be considered an integral part of the phased-array antenna system and developed with it, since it would undoubtedly be a dedicated processor offering no realistic opportunities for time-sharing. The processing requirements for phased-array management should therefore not be considered as a part of the dispersed processing network.

Initially, not all interrogator sites may incorporate a phased-array antenna system (although all primary interrogator sites will probably be separated from skin-radar sites, as stated earlier). The identification of this processing as a separate function also allows for easier compatibility when changeover is made to the phased-array antenna system. In addition, any site equipped with a small phased-array system could be expanded to a larger phased-array system with minimum perturbation to the processing performed at the remote site.

3.8 Processing at Skin Radar Sites

The discussion thus far has referred primarily to processing that can be performed at the interrogator sites. Skin-radar sites also offer opportunities for processing, including radar data reduction, coordinate extraction and transformation, and data formatting for direct communication with the central ATC computer. The resulting compaction of information, when combined with data buffering at the radar site to average out the fluctuations in data rate, might reduce the required bandwidth for communications from radar site to control center.

Automatic reduction of radar data is a rather sophisticated processing task. The radar signal includes several range sweeps while the target aircraft is in the main beam, and all of these range sweeps must be correlated and processed to extract a unique set of target coordinates. The processing must be sophisticated enough to reject false alarms due to noise and to spurious returns, and to decide automatically whether the radar return is most compatible with the hypothesis of one, two, three, etc. targets within the beam. Coordinate determinations and target-multiplicity decisions must be made with high reliability, particularly in conflict situations which unfortunately are the most difficult to cope with technically. These problems will become worse as aircraft traffic density increases.

The most common present practice is to solve these problems "by eye." A trained human operator viewing a high-quality scope display has formidable (though partially subconscious) weapons for solving such problems. Under good conditions, it is commonly found that his performance can compare favorably with that of the "mathematically ideal observer," based on maximum likelihood processing. He can also recognize and effectively cope with a variety of fault situations. Some reservation is felt about replacing the operator by unattended automatic processing at the radar sites.

It is recognized that the technology for this automation is available and well-understood, and furthermore it is planned to automate the extraction and formatting of radar data at the control centers. Nevertheless, there appears to be less technical risk in carrying out the automation at a control center with its wealth of backup resources (including the presence of operators and the possibility of alternate ways to obtain the data) than at a radar site which is unmanned except for maintenance and security functions. Although it is also possible to think of backup for processing failures at the radar site, this would require a standby wideband link, the very existence of which would cancel the primary advantage of processing at the radar site.

It is planned that the role of skin-tracking radars in the ATC system will be downgraded to that of secondary surveillance, and there may ultimately be fewer radar sites than interrogator sites. Furthermore, none of the control signals involving IPC, data link, etc. will be routed via the radar site.

In summary, because of the contemplated use of the skin-return radar as a secondary surveillance system, and because of the need of a somewhat involved coordinate-extraction device for the complex radar pattern, it appears doubtful that remote processing would also be included at the skin-radar site.

4. SUMMARY

An analysis has been performed of the potentialities and problems involved in assigning some computer processing and control functions to the remote sites in an upgraded third generation air traffic control system. It has been concluded that the interrogator sites offer the most fruitful opportunities for remote processing. System reliability requires that the ARTCC maintain managerial control over those processing tasks which can be construed as control functions. "Floating control," whereby a remote site seizes control of some vital function without explicit authorization from the control center, probably cannot be tolerated under any circumstances. This stricture against floating control implies a requirement for an ultra-reliable, low data rate orderwire control net. This orderwire net is indeed feasible and inexpensive.

Several tasks reasonably can be assigned to the remote sites, either in a primary or a backup role. These tend to be those processing tasks for which either (a) the needed inputs are locally derived, such as in the task of extraction, compaction, and formatting of positional data, or (b) the outputs are utilized locally, as in the management of data interchange between the remote site and aircraft. Also considered as reasonable candidates are certain "dynamic backup" functions.

The candidate tasks for remote processing which have been considered in this report are:

- Data extraction, compaction, and coding,
- Roll call generation,
- Data link management,
- Ground communications management,
- IPC service.

Several of these tasks require that tracking be performed at the remote site, although these tracking data do not necessarily have to be as complete as the tracking data available at the control center. Even if tracking data are not available at the remote site, a reasonable remote processing assignment at each interrogator site would be the extraction, compaction, and input format encoding of acquired data. In fact, a processing system with only these remote assignments will be considered seriously in future work. This minimal system can also be regarded as an evolutionary step toward a more expanded remote processing scheme. If it is decided to perform simultaneous tracking at the remote site, it then becomes feasible to perform the other candidate remote processing tasks.

It is specifically recommended that the phased-array control not be considered as a dispersed processing task. The phased-array controller should be dedicated and developed as part of the phased-array antenna system.

On this basis, it appears likely that our future work will give primary consideration to two types of distributed remote processing assignments:

1. Minimal Assignment - in which data extraction, compaction, and input encoding are performed at the remote site (with no tracking being performed at these sites).
2. Expanded Assignment - in which tracking (in some form) is performed parallel at the remote site. This would allow adding any or all of the remaining candidate remote processing tasks.