NBSIR 73-422

A Study of Air Traffic Data Requirements and Sources for FAA Analyses

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U. S. DEPARTMENT OF COMMERCE
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1.0 PURPOSE AND OVERVIEW

This report describes activities undertaken by the National Bureau of Standards (Technical Analysis and Applied Mathematics Divisions) on behalf of the Federal Aviation Administration (FAA)* to assess the practicability of establishing a single file or a set of files of standard reference air traffic data samples, and to specify the characteristics of such files as might be feasibly constructed. These prospective files would, in concept, serve as a common data base for ongoing and (anticipated future) forecast and analytical investigations relevant to the accommodation of air traffic in the National Airspace System (NAS).

It is well known that existing traffic data are not at all complete, if only because of huge gaps in information about VFR operations. Consequently, basic interest was focussed on the extent to which current, accessible data satisfy analytical and forecast needs, the extent to which existing raw data in diverse collections could be brought into user-accessible files and, if the shortfall were substantial, the magnitude of the task of redressing it.

The study entailed surveys of past and present air traffic data collection activities, of existing data files and of all identifiable users of air traffic data (i.e., groups within FAA and those of its contractors whose work requires air traffic data as input). In the present context, "survey" comprises a spectrum of actions: literature search, perusal of reports and manuals, examination of file specifications and data listings, visits to operational and research facilities, and several rounds of interviews with data collectors and data users.

Information produced by the surveys was structured into tables based on definitions of data types, uses and availability, then analyzed. In brief, the analysis leads to the conclusion that, with some intensification of current data recording procedures, a moderately comprehensive data base can be created and organized in five data files, split into three groups categorized according to the flight operations under primary consideration: terminal, "CONUS" enroute, and oceanic. Guidelines were developed for identifying and treating a hierarchy of critical priorities in data requirements, data collection and processing, and redefinition and reduction (or, in some cases, expansion) of user data requirements. Estimates were made of the resources required for producing a data base which would satisfy user needs for all anticipated flight conditions.

2.0 INTRODUCTION

In addition to being charged with day by day management and operation of the National Airspace System, the FAA is also responsible for the development of improved systems and procedures required to keep the system responsive to changing aviation user needs. In the course of developing and validating these system and procedural improvements, analytical studies which require air traffic situation data as inputs are conducted by FAA in-house groups and by outside contract groups. Over the years the FAA and its predecessor organizations have collected and continue to collect a considerable volume of air traffic activity data, but these data in their present form are not usually suitable for direct use in the analysis of air traffic situations. Consequently, those who carry out various analytical studies must manipulate the existing air traffic activity data into those traffic-describing formats which best fit their particular requirements. As a result, two independent research groups working on the same air traffic situation problem may base their studies on two quite different sets of data, each group employing its own assumptions to define its representation of that traffic situation. This can tend to reduce confidence in analytical results, and it precludes valid comparisons of independent efforts or approaches in investigating the same problem. For example, there have been cases where two contractors worked in parallel on a common problem, taking different approaches. Each analysis produced results demonstrating that its approach was reasonable. However, if the different assumptions and associated air traffic descriptions were interchanged, neither analysis would show satisfactory results. Such difficulties illustrate the need for standard air traffic sample reference data usable by most investigators. This study explores the feasibility of satisfying that need.

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*A list of mnemonics and abbreviations used in this report appears in the Glossary on p. 47.

The traffic samples required for these studies can be catalogued under three broad data structure classes: tracks, snapshots and activity summaries. A track is a complete flight history (in time and space) of an aircraft, usually recorded at intervals of about 4 seconds (the sweep rate for most commonly used FAA radar). A snapshot is an instantaneous status report on all tracks in some portion of airspace. (Snapshots normally include instantaneous speed and direction, which are obviously unnecessary for tracks. Both tracks and snapshots might include altitudes, profile information, meteorological and other "external" data.) Activity summaries are aggregates of the type found in annual activity reports, but possibly tailored for particular studies with additional time and geographical details (e.g., "hourly activity by a/c class over the northeastern U.S. in blocks 10 nautical miles square x 5000 ft. altitude layers").

It is clear that some studies, say of handoffs in ATC, may require a small set of tracks, and that neither snapshots nor aggregates, no matter how extensive or detailed, would be very useful. On the other hand, analyzing traffic "clutter" requires snapshots; detailed single tracks or exhaustive summaries (unless very fine-grained) would not suffice. For estimating various levels of manpower and equipment requirements, only large numbers of tracks or snapshots over time, i.e., good summary statistics, are appropriate.

Data sample requirements can also be structurally differentiated by the "typicality" relevant to a particular study. Some analyses require "typical" data, while others refer only to "critical" data, such as various kinds of peak traffic (or in one ongoing CAS study, low activity periods). "Typical" may range from specifying averaged data to deletion of statistical outliers (e.g., peaks). In statistical terms, the distinction is analogous to representations of "mean", "median" and "mode". In some instances the probabilities of occurrence of various traffic situations may be required inputs.

For this study, data requirements were explored initially in meetings with all identifiable FAA in-house groups engaged in analytical efforts requiring air traffic situation data. Meetings were also held with FAA contract groups who are doing (and are expected to continue) similar support analyses. The purpose of these meetings was to gather information on the groups' current and anticipated requirements for present and future air traffic data. Their requirements, in fact, include not only air traffic data *per se*, but also other relevant information on topics such as aircraft performance characteristics, airborne equipment, and routing. In addition to meeting with the data using groups, the study staff met with FAA personnel from Management Services and the Office of Aviation Economics in order to obtain a thorough understanding and knowledge of existing FAA air traffic data sources and forecasting procedures.

The information obtained from these direct contacts was evaluated and aggregated to identify data which will satisfy most of the requirements expressed by the data users. Two data sets were specified for terminal area requirements, two sets for en route requirements, and one set for oceanic requirements. These data sets will not satisfy all input requirements for all anticipated analysis efforts. Depending on the type of study, supplemental information will be required in some cases and is identified in various parts of this report. To avoid possible misunderstanding, we emphasize that the purpose of this analysis was not (nor is it an appropriate goal) to develop data or traffic sample models which can be used as *direct* inputs to analyses. The analyst who uses standard data sets must design an air traffic data model to fit his specific problem or method of analysis. The intent here is to provide common data and sources to be used by all analysts as a consistent basis for and input to any special-purpose traffic situation descriptions.

3.0 DATA REQUIREMENTS

3.1 Users

In order to identify FAA traffic data requirements the NBS project staff discussed with FAA and contractor personnel various current and projected programs which might utilize air traffic situation data. Several of these programs are described below. The list includes all known types of analyses which will be required by the agency in the next few years, although some specific efforts may have been omitted.

Micro-Wave Landing System (MLS)

A micro-wave landing system (MLS) is being developed as a possible replacement to the present conventional instrument landing system (ILS). The MLS is being designed to provide more precise heading and altitude information in the cockpit; should permit all-weather operations with greater safety; would allow curved approaches and a flexible glide slope angle; and might permit simultaneous IFR approaches to parallel runways at lesser separations than are now required. Studies of the performance of proposed or prototype MLS systems, relative to these goals, are anticipated. Current MLS studies are aimed at ensuring that particular systems meet technical performance specifications, and thus do not require traffic data. However, such data will be necessary in order to evaluate the operational effectiveness and safety of an MLS system, how the curved approaches and variable glide slope angle operate in the ATC environment and how these capabilities can best be exploited, and whether the system will permit safe conduct of simultaneous IFR approaches to close parallel runways.

Ground Guidance

As the system of airport runways and taxiways becomes larger and more complex, safe and effective control and guidance of aircraft on the ground, particularly under conditions of poor visibility, become increasingly difficult. Several different systems are being considered to accomplish this function and it will be necessary to evaluate their effectiveness under different traffic situations.

Frequency Spectrum

Frequencies in the vhf spectrum, currently separated at 100 and 50 kHz intervals are assigned to control positions in ATC facilities for voice communications. Similar frequencies are also assigned to various surveillance and navigation activities. As air traffic activity increases and additional ATC facilities are established, the frequencies now available for assignment will no longer accommodate the demand by all aviation users. Since the probability of additional frequencies being allocated to the ATC system is low, it might be possible to increase the number of available frequencies by reducing frequency separation in the presently allocated spectrum. If such a reduction is to be implemented, care must be taken in the reassignment of frequencies to control positions and other functions, since frequency protection from neighboring facilities must be maintained. Thus it is necessary to evaluate the magnitude of the demand as a function of expected traffic levels, to be able to assess how soon and where frequency shortages will become acute and to analyze and plan any change in frequency reassignment before the situation becomes critical.

STOL

Short takeoff and landing (STOL) vehicles may be introduced into the civil air fleet at some time late in the decade. Special STOL-ports may be built near city centers so that STOL passengers can be delivered closer to their ultimate destinations than they are with today's airport system. STOL aircraft may also be expected to use existing airport facilities, either sharing runways with conventional aircraft or, most likely, using special STOL runways. Since STOL vehicle landing and takeoff characteristics (speed and flight profile) are significantly different from those of conventional aircraft, it is necessary to analyze the interaction of the two types of aircraft in the common terminal area.

Wake Turbulence

Wake turbulance, the disturbance of the air behind a heavy aircraft, particularly at and immediately prior to touchdown or lift off, has become a more severe safety problem since the introduction of the jumbo jets (B747, DC10, L1011). As a result, increased separation (5 mi.*) of aircraft following a large jet is required. As better (more accurate) means of terminal navigation and surveillance are developed, it may well be that wake turbulence will be the major constraint in determining minimum safe separation distances between aircraft. Traffic data will be required in the evaluation of increased separation requirements and other rules changes caused by wake turbulence problems.

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* Nautical miles.

Pollution

As air pollution in our cities becomes more critical, airports may have to limit or curtail operations during pollution alerts. Although some experts have expressed the opinion that the contribution of aircraft toward severe pollution is slight, many local jurisdictions are considering the possibility of curtailing aircraft operations, for they are more easily controlled than other pollutant sources and their pollution is more visible. A second type of aircraft pollution has also come to the fore, namely noise pollution. Noise abatement procedures have been instituted at several large airports, approach and departure routes and altitudes being specified and reduced engine power prescribed in order to minimize noise and to concentrate it in areas affecting the smallest population. To assess the effect of aircraft-caused pollution on the near-airport population and to evaluate means of reducing it (with regard to the degree of reduction and also to the economic impact of curtailed operations), it is necessary to have air traffic data.

Before and After ARTS III and NAS Stage A

The FAA is currently completing the installation of ARTS III equipment at large and medium hub airports and of NAS Stage A in ARTCC's,in order to automate some air traffic control functions. To evaluate these systems ability to provide increased controller workload capacity and/or additional operational safety, it is necessary to compare controller activities and aircraft operations before the equipment is operational with those after it has been in use for several months. This effort requires traffic data for these two time periods.

Capacity

Traffic congestion and accompanying delays are being experienced at some of the highest activity terminals, and in a few cases restrictions have been placed on the acceptance of IFR traffic. The increased use of wide-bodied jets by the air carriers will delay the onset of system saturation only a short time, and may in fact be offset by the increasing volume of general aviation IFR traffic. The terminal area is the critical point with respect to the capacity of the ATC system. However, it should be noted that not all terminals are heavily congested, and that most terminals which experience backups during peak hours have excess capacity at other times. Thus estimates of future traffic levels are needed to assess the magnitude of the problem of restricted capacity, to evaluate its consequences, and to investigate methods of relieving the situation.

Although the most critical part of the ATC system is the terminal area, it is necessary as well to study the capacity of the en route system, both to ascertain what residual capacity is available and to identify points in the system which are near saturation. It is also necessary to evaluate the effects of possible route and procedure changes on the capacity of the system. Capacity of the en route ATC system may be defined in two ways: one involving the physical capacity of the airways structure under current separation procedures and the second related to the workload capacity of controllers under current staffing and sectorization levels. Studies utilizing both concepts are needed, but the second clearly addresses the more critical situation.

General Aviation (GA)

Most of the traffic data regularly collected by the FAA concerns IFR traffic, traffic handled by FAA air traffic control facilities, or traffic which files flight plans. The bulk of general aviation (GA) traffic flies VFR, is out of and into non-tower airports, and does not file a flight plan. Its main contact with the FAA system is through Flight Service Station (FSS) activities such as pilot advisories and briefings. However, it is virtually impossible to relate such FSS activity directly to GA traffic volume and activity. The only data collected by the FAA which include all of GA are concerned with aircraft (the aircraft registration data) and airmen (pilot licenses and medical data). Special surveys have been and are conducted for specific purposes, including, for example, the CAP survey [19]* and FAA surveys at airports, which are candidates for towers or navigation aids. The CAP survey varies in precision from area to area, hence may be quite unreliable as a basis for a nationwide data base. The special surveys at FAA facility candidate airports are

* Numbers in square brackets in the text refer to articles in the reference section, page 46.

limited to fairly high activity airports, and so there is no record of the substantial GA traffic at lower activity airports. Overall, sources of GA data are meager or nonexistent.

With an expected increase in general aviation IFR operations and proposed regulation changes affecting GA flights, more data on present day GA activity are required. Whereas GA now constitutes less than half of the total IFR operations, it is projected that GA will soon become the major portion. It is therefore necessary to have better information on the flying habits of this segment of the flying population. In addition, the institution of Terminal Control Areas (TCA) and other proposed rules changes may increasingly segregate the VFR general aviation flight from IFR traffic. To assess the effects (including changes in safety as well as possible economic hardships) of such rules, it is necessary to have a more accurate representation of GA traffic levels in various types of terminal areas.

Synchronous Garble

Beacon responses from two aircraft within the same 2° band width and within 1-1/2 mile slant range from the same beacon interrogator source interfere with one another, garbling both responses. It is possible to decode the garbled responses if not more than two aircraft are involved. It is therefore desirable to investigate the frequency with which three or more aircraft will be in this situation, as an increasing fraction of traffic chooses, or is required, to use a transponder.

Communications Requirements for Upgraded Third Generation (UTG) Equipment

In the automated ATC environment, various subsystem elements must communicate with one another. Examples include (1) flight plans sent from an FSS to an ARTCC, from the ARTCC to a tower or back to the FSS, and from one ARTCC to another; (2) messages from the computer to print flight strips at the appropriate sector positions; (3) messages from sector positions back to the computer to update flight records; (4) voice messages between controllers and pilots in aircraft under control; (5) radar signal responses received from aircraft; and (6) FSS advisory activities. Additional communications requirements may be imposed as presently non-automated activity is automated. Estimation of the equipment required rests on traffic data.

Area Navigation (RNAV)

RNAV is a means of providing navigation which permits straight-line flights from point of origin to point of destination. Airborne computer equipment determines the route by calculating waypoints given by pre-determined distances from a VOR. The pilot then navigates to and from en route waypoints, using the VOR bearing indicator in the same manner as in flying to or from an actual VOR. Airborne RNAV equipment varies in cost depending on its complexity and sophistication, but the least expensive set presently costs about $5,000. Owners of small aircraft will therefore be less likely to invest in this equipment than will owners of larger, more expensive, aircraft.

RNAV equipment is increasingly being used as pilots and controllers gain experience with it. Since straight-line routes may intersect one another as well as conventional routes, it has already become necessary to establish designated RNAV routes and approach procedures to facilitate handling of RNAV flights by controllers. Some RNAV routes may coincide with existing air routes, but in most instances they will be different. It is projected that in the post-1982 period only RNAV routes will exist in the altitude structure above 18,000 feet. To plan for the interim period it will be necessary to analyze comparative usage of the two systems and to investigate their interaction.

Collision Avoidance System (CAS)

One proposed type of CAS relies for its distance calculating ability on the availability of accurately synchronized time signals. These signals, broadcast from ground stations, would be recevied by all CAS equipped aircraft within some radius (say about 60 miles) of a station. The aircraft could thus continually maintain the calibration of their airborne clocks. Aircraft beyond range of a ground station would have to recalibrate their clocks with those in aircraft within broadcast range of a station, with a commensurate degradation in accuracy of distance calculations. It is assumed that, because of the high cost of equipment, only air carriers would be able to provide recalibration services to other aircraft. In order to know where the accurate time ground stations should be located, it is necessary to know where air carrier traffic is not sufficiently dense to provide recalibration service. Of course, if such low density areas also have very low levels of other traffic, the service may not be warranted: the tradeoffs of cost and coverage for low traffic levels must be evaluated.

Sizing NAS Computers

The automated NAS system uses several different versions (implying different size configurations) of the IBM 9020 computer. Since this equipment is unique to the FAA application and will be in production only until the original purchase order is filled, any subsequent equipment orders will incur start-up time lags and associated costs. It is therefore necessary that computer equipment requirements be accurately specified before the initial production cycle ends.

Interrogator Interference

As an aircraft nears U.S. airspace, it must be identified as friend or enemy for air defense purposes. Airborne interrogation equipment (IFF) is available to perform this function automatically, but it is subject to jamming, either deliberately or due to the proliferation of electromagnetic radiating equipment. It is therefore necessary to study how often jammed IFF response might occur, to investigate methods of detecting deliberate jamming, and to develop means of identifying intruders in spite of the various possible interferences.

TACAN and DME

The distance-measuring portion (DME) of the tactical navigational aid (TACAN) is interrogated by airborne equipment to provide the pilot with distance information from the navaid site. With the radial information normally provided by a passive VOR (the combination with the DME being termed VORTAC), position can be determined with a single navaid. As the number of aircraft possessing the DME equipment increases, there is danger of saturating the ground equipment, hence it is necessary to evaluate when and where DME saturation is likely.

Frequency Reassignment for Enroute Sectors

Each sector control position in an ARTCC is assigned a discrete 50 kHz radio frequency for voice communication between pilots and the controller of that sector. Frequencies for adjacent sectors must be sufficiently separated to avoid interference. As traffic increases and as rules and procedures change, sector boundaries are redrawn and new sectors may be formed, with frequencies reassigned whenever new sectors are created. Changes in traffic patterns affecting relative traffic levels in different sectors may also necessitate frequency reassignment.

OMEGA

The standard short range air navigation system over the U.S. land area utilizes VOR, which is limited to line-of-sight operations, but no system with equivalent accuracy exists for oceanic navigation. The most common navigation system now in use for trans-oceanic air travel is inertial navigation, which does not require ground stations, but which computes present position from known past positions by means of a gyro-compass, speed, and weather data. Most aircraft carry two inertial systems, for redundancy and cross-check capability. Loran navigation is also available for use by both aircraft and marine vessels. However, Loran relies on signals broadcast from ground stations and its coverage is not complete, leaving a gap in the middle of the ocean where another system must be used. Satellite navigation systems have been considered but were not recommended in the ATCAC report [15] because of their cost.

Another navigation system, OMEGA, has been proposed for adoption. It broadcasts vlf signals, and only a small number (five or six) of ground stations would provide complete coverage of the Northern Hemisphere. Information for trans-oceanic air traffic is required to assess the benefits of such a system in terms of increased safety or a reduction in the present trans-oceanic separation standards.

Flight Information Region (FIR) Reconfiguration

Coastal radar equipment provides surveillance coverage of flights for only a limited distance over the ocean. In the strictest sense, oceanic flights are not under control, since their movements cannot be monitored independently by ground personnel. Over the ocean, where radar coverage is lacking, Flight Information Regions

(FIR's) have been established. In these areas, ground personnel from (and in) the country which has control responsibility for the particular region advise aircraft on conditions and monitor positions as reported by the pilots. As traffic increases and traffic patterns change, it is necessary to reexamine regional boundaries to determine if a new configuration (size or number) of regions might expedite oceanic air traffic.

Satellite Navigation Power Requirements

Satellite navigation systems are expensive, in large part due to the power requirements of on-board equipment. Since a satellite's life is expected to be at least five years, care must be taken when estimating power requirements that the initial supply of power is sufficient for the full span. This must be carefully balanced against the extra launch cost of additional payload entailed by overestimating power requirements.

3.2 Data Required

The programs described above may be broken down into three categories: those where studies are concerned primarily with the terminal area, those concerned with the en route ATC environment, and those requiring data on oceanic flights. Each category has unique data requirements, which can be described under the following headings:

a. geographic area
b. desired traffic level
c. type of traffic sample
d. time length of sample
e. traffic to be included
f. data items required.

A more complete description of the data requirements under each of these headings appears below.

3.2.1 Terminal Area Data

a. Geographical area - Users of terminal area data require them for one or more of four different sets of terminal environments. Those who are studying problems for which high traffic density is the critical factor require data from several of the large and medium terminals (as determined by number of operations, possibly in various categories such as itinerant or instrument operations). For some applications the density of the environment is only one of several factors which are being investigated. In this case, data are desired from a relatively small number (say less than 10 or 12) of airports which can be said to be representative of the whole spectrum of airport environments. Of course, care must be taken in choosing such representatives to insure that all important types of environment are included; it may not be possible to restrict the representative set to as few as 10 or 12 airports. Depending on expected applications, the representative set of terminals may or may not include non-tower airports, for which data are difficult to obtain. Some analyses may focus on GA traffic activity, the major user of such airports, so the category "non-tower airports" has been separately included for such applications. Each of the other three categories refers to only a single terminal or airport, providing data required by most studies which focus on landing and takeoff operations and ground activity. Some studies, however, need data on all flights airborne within a radius of 30 to 60 miles of an area and need to know about any flight in the airspace, whether it lands or takes off from the major terminal, from a satellite airport in the area or is a through flight. An additional category provides data for all flights airborne in a large hub area (defined by the FAA as SMSA's whose airports have at least 1% of the total U.S. enplaned passengers). These hubs usually contain at least one major terminal and several smaller airports.

b. Desired traffic level - Since the FAA ATC system is designed to facilitate safe traffic flow, many system elements must be able to handle any traffic level which is attained. Design parameters are therefore determined from peak traffic conditions. Other analyses must evaluate system performance under average or typical traffic conditions.

c. Type of traffic sample - Although many FAA studies require traffic data, there are differences from study to study in the specific data needed. One type of needed data is the instantaneous "snapshot", which provides a complete picture of all airborne aircraft at a single point in time, including the aircraft positions and other relevant information about each aircraft. The snapshot may be required for studies concerning relative positions of aircraft at a given moment. Another type of terminal area data concerns counts of operations per time interval, including such activity categories as instrument approaches, all approaches (landings), or all takeoffs, each of these usually being provided as hourly arrival and departure rates on each runway. Such data might become inputs to simulation programs for subsequent calculations of any required relative position data. In addition to data on airborne operations, there is some need for information about ground operations at the more complex terminals.

d. Time length of sample - The snapshot described just above corresponds to an instantaneous picture of the situation in the sky, with one-minute periods, perhaps, used as surrogates for the instant. Studies requiring simulation of terminal area operations would most often require hourly data for as many as three hours, and some would call for traffic throughout an entire day. For rapid changes in traffic levels it may be desirable to have data for 15-minute intervals (rather than hourly) over the period of interest. In addition, some studies may require data on how traffic levels vary weekly and seasonally relative to usage in the base time period.

e. Traffic to be included - If data on all traffic were equally easy to obtain, a data sample could include everything, allowing selection of the most relevant information for particular studies. However, since it is more difficult to obtain data on some classes of traffic (notably VFR traffic not filing flight plans) than on others, it is desirable to know if some studies might be performed with a smaller (and presumably more easily obtained) set of data. IFR traffic is already recorded on flight strips and is therefore most readily available. On the assumption that those VFR flights for which flight plans are filed are made by the larger and better equipped aircraft, one might obtain from flight plans the data required to conduct studies regarding those aircraft which might be expected to carry the more sophisticated types of new equipment. Data are not currently collected on VFR flights not filing plans, and would have to be obtained by special surveys if data are required on all flights.

f. Data required - Various pieces of data are needed for the different studies. Position is included in snapshot data, but must be simulated by studies using operations rates. Some analyses need data broken down by category of flight rules (IFR or VFR), by user category (AC, GA, or MI), or by flight type (local or itinerant). Flight duration has to be an input for some studies where the persistence of various conditions must be identified, or in the form of distributions over all flights where specific tie-ins cannot be established. These data items include aircraft type (sometimes called mix), avionics carried (transponder, communications equipment, navigation equipment), assigned or actual altitude, and speed and heading. Some studies need data on the fraction of aircraft executing such maneuvers as turns, climbs or descents. In addition, it is necessary to have information on the utilization of communications equipment, and message frequencies and length. Finally, some systems under study will have special airborne equipment associated with them. For these, the fraction of aircraft having such equipment will have to be known by the user, but this information will not be a part of the traffic data.

3.2.2 En Route Data

a. Geographical area - En route studies encompass larger geographical areas than do the terminal studies. Some analyses require data for the airspace over all of CONUS (the contiguous 48 states); others require the high density Northeast and Southwestern U.S. areas. A third category includes en route sectors from different ARTCC's. The sample set of sectors should be as small as possible, consistent with containing representatives of as many different types of en route environments as possible.

b. Traffic level desired - As with terminal area studies, most en route analyses require data either for peak or for average traffic levels. However, one study concerned with adequate coverage by airborne equipment, has a specific need for data on low traffic density areas.

c. Type of traffic sample - As with the terminal area analysis, some users require snapshots containing positions of all airborne aircraft; others would use only counts of the aircraft airborne at a given time. A third group calls for the route flown by each flight or even the actual track, including deviations from the planned route, and a fourth calls for the origin and destination of each flight, but not the route or track flown.

d. - f. The categories under the headings "Time length of sample" and "Data required" are the same as those described for the terminal area.

3.2.3 Oceanic Data

a. Geographical area - Several studies being conducted by the FAA require data on trans-oceanic flights, primarily in the North Atlantic area. One study requires data from oceanic sectors of the NAS system, and another concerns the evaluation of a world-wide navigation system, requiring data from all over the world. All studies, with the exception of that of NAS oceanic sectors, call for data on flights over the ocean in areas not covered by radar or ground-based navigation systems, areas in which it is difficult to obtain data on actual tracks of aircraft, but may use intended flight paths.

b. Desired traffic levels are the same as for the terminal and en route data sets, namely peak and average densities.

c. Types of traffic sample desired include three of the categories described for en route data: the snapshot, the route flown, and the flight described by origin and destination without reference to route.

d. - f. The remaining categories are the same as itemized above for terminal and en route data.

3.2.4 Requirements Matrices (Table 1)

The following matrices display the data requirements expressed by users and interpreted by the NBS project staff in accordance with their experience in modelling and analysis. An "X" means that the indicated user requires the data item, whereas a blank means that it is not now expected to be required.

3.2.5 Non-Traffic Data

In the course of discussions with people analyzing air traffic control problems and systems, they expressed a number of desires for data not specifically on air traffic. Most of these data are available from sources within the FAA or other sources known to the FAA. They concern ATC system, airport, and aircraft characteristics, navaid and radar information, and weather data, and are listed below.

1. Air traffic control system characteristics
   - a. procedures
   - b. airways, SIDs and STARs, intersections
   - c. sector boundaries
   - d. computer system operations
2. Airport characteristics
   - a. runway configurations and standard operation procedures
   - b. terminal locations
3. Navaid and radar data
   - a. locations
   - b. coverage (3-dimensional)
4. Weather
5. Aircraft characteristics
   - a. aircraft operating characteristics
   - b. airborne equipment.

4.0 DATA SOURCES

4.1 Existing Sources

The FAA collects a substantial volume of air traffic data on that portion of aviation activity which uses its ATC and FSS facilities and services. These data range from manually updated flight strips in air traffic control towers and air route traffic control centers to the vast amount of data contained in and outputted by the

Table 1. Terminal Area Matrix

Data Item \ USER	MLS	Ground Guidance	Frequency Spectrum	STOL	Wake Turbulence	Pollution	Before & After ARTS III	Capacity	GA	Synchronous garble	Communications requirements for UTG Equip.
Geographical Area:											
1. Large and medium terminals	X	X				X	X	X			X
2. Representative terminals	X			X	X			X	X		
3. Non-tower airports								X	X		
4. Large hub areas			X					X		X	X
Traffic level desired:											
1. Peak	X	X	X		X	X		X	X	X	X
2. Average		X		X	X		X	X	X		
3. Low density											
Type of traffic sample:											
1. Snapshot			X				X	X		X	X
2. Instrument approaches	X						X				X
3. Terminal area arrival rates		X		X	X	X		X	X		
4. Terminal area departure rates		X		X	X	X		X	X		
5. Ground operations		X									X
Time length of sample:											
1. Instant			X							X	X
2. Minute											X
3. 15 Minute											X
4. Hour	X		X	X	X			X	X		
5. 3 Hour		X				X	X	X	X		
6. Day						X					
7. Diurnal Fluctuations		X				X	X	X	X		X
8. Seasonal Fluctuations									X		
Traffic to be included:											
1. AC only											
2. IFR only	X										
3. IFR and larger VFR				X			X				
4. All traffic		X	X		X	X		X	X	X	X
Data required:											
1. Category of flight rules IFR/VFR							X	X	X		
2. User category AC/GA/MI									X		
3. Flight type-local/itinerant								X	X		
4. Flight duration			X					X	X		
5. Aircraft type	X	X		X	X	X	X	X	X		X
6. Avionics	X		X				X		X	X	X
7. Altitude	X			X				X	X		X
8. Speed	X	X		X	X	X		X	X		X
9. Heading					X				X		
10. Maneuvering			X				X				X
11. Communication rates	X	X	X	X			X	X			X
12. Communication message length			X				X	X			X
13. Special airborne equipment	X			X							

Table 1. Enroute Area Matrix

Data Item \ USER	RNAV	CAS (time)	Before and after NAS stage A	Capacity	Sizing NAS computers	Communications requirements for UTG Equip	IFF/ECM Interference	TACAN and DME	Frequency Assignment For Enroute Sectors
Geographical area:									
1. All of CONUS	X	X			X		X		X
2. Representative enroute sectors			X	X	X	X		X	
Traffic level desired:									
1. Peak	X			X	X	X	X	X	X
2. Average	X		X	X					
3. Low density		X							
Type of Traffic Sample:									
1. Snapshot		X	X	X	X	X		X	X
2. Track flown				X			X		
3. Route flown	X			X					
4. Origin/Destination	X								
5. Instantaneous count					X	X			X
Time length of sample:									
1. Instant		X			X	X		X	X
2. Minute					X	X			
3. 15 Minute						X			
4. Hour				X			X		
5. 3-Hour			X	X					
6. Day	X						X		
7. Diurnal fluctuations	X			X	X	X			
8. Seasonal fluctuations	X								

Table 1. Enroute Area Matrix (Contd.)

Data Item \ User	RNAV	CAS (Time)	Before and After NAS Stage A	Capacity	Sizing NAS Computers	Communications requirements for UTG equipment	IFF/ECM Interference	TACAN and DME	Frequency assignment for enroute sectors
Traffic to be included:									
1. AC only									
2. IFR only					X				X
3. IFR and larger VFR	X		X						
4. All traffic		X		X	X	X	X	X	
Data required:									
1. Category of flight rules IFR/VFR	X		X	X	X				
2. User category AC/GA/MI	X	X			X				
3. Flight type-local/itinerant	X			X					
4. Flight duration	X			X					X
5. Aircraft type	X		X	X	X	X		X	
6. Avionics	X	X	X		X	X	X	X	X
7. Altitude	X			X	X	X	X	X	X
8. Speed	X			X		X	X	X	
9. Heading				X			X		
10. Maneuvering			X	X		X	X		
11. Communication rates			X	X	X	X			X
12. Communication message length			X	X		X			X
13. Special airborne equipment	X	X						X	

Table 1. Oceanic Area Matrix

Data Item \ User	OMEGA	Sizing NAS computers oceanic sectors	FIR reconfiguration	Satellite navigation, power requirements										
Geographical Area:														
1. North Atlantic			X	X										
2. U. S. Coastal		X												
3. All oceans	X													
Traffic Level Desired:														
1. Peak		X	X	X										
2. Average	X													
3. Low density														
Type of Traffic Sample:														
1. Snapshot		X	X	X										
2. Route flown	X													
3. Origin/Destination	X		X											
Time length of sample:														
1. Instant		X												
2. Minute		X												
3. 15-Minute														
4. Hour														
5. 3-hour														
6. Day	X		X	X										
7. Diurnal fluctuations		X	X	X										
8. Seasonal fluctuations	X		X											

Table 1. Oceanic Area Matrix

Data Item \ User	OMEGA	Sizing NAS computers oceanic sectors	FIR reconfiguration	Satellite navigation, power requirements									
Traffic to be included:													
1. AC only													
2. IFR only	X	X	X	X									
3. IFR and larger VFR													
4. All traffic		X											
Data required:													
1. Category of flight rules IFR/VFR		X											
2. User Category AC/GA/MI	X	X											
3. Flight type-local/itinerant													
4. Flight duration	X		X										
5. Aircraft type	X	X											
6. Avionics	X	X		X									
7. Altitude	X	X											
8. Speed													
9. Heading													
10. Maneuvering													
11. Communication rates		X		X									
12. Communication message length				X									
13. Special airborne equipment	X			X									

NAS and ARTS computer systems. The data are generated in the ATC facilities during the course of conducting day-to-day air traffic control and management functions. Except for that portion of the data which is normally transmitted to FAA Headquarters as the basis for FAA published air traffic information (see references [3], [11], [12], and [18] for example) and other in-house uses, the data are destroyed after some specified interval of time. Most of the data used and published by FAA Headquarters, although providing long term (usually annual) measures of air traffic activity, are primarily workload factors which serve as a basis for ATC facility staffing. The primary sources of these data are as follows:

FAA Form 3588	- IFR Peak Day Flight Plan Summary
FAA Form 3444	- FSS and CS/T Flight Plan Survey
FAA Form 7230-12	- ARTCC Operations and Instrument Approaches, Monthly Summary
FAA Form 7230-11	- Airport Operation and Instrument Approaches, Monthly Summary
FAA Form 7230-13	- Flight Service Station Monthly Activity Record
FAA Form 7230-15	- International Flight Service Station Flight Service Activities

With the possible exception of the IFR Peak Day data, the above sources all provide long-term activity data which are not adequate for use in analyses requiring short-term or instantaneous air traffic situation data.

In addition to the above air traffic activity data sources, other related data sources are available to users. These are:

The Official Airline Guide [14]
CAB Airport Activity Data [1] which cover air carrier operations, passenger emplanements and mail cargo data.
Voice tapes recorded in the ATC facilities
Aircraft and airman registration data maintained by the FAA in Oklahoma City
Special air traffic studies such as the Los Angeles basin model [7], [8], and [9] and the Long Beach surveys.

4.2 Requirements-Sources Matrix (RSM), Table 2

The Requirements-Sources Matrix (RSM) has the same structure as the requirement matrix given in Table 1, differing only in the matrix elements. Whereas an "X" in the requirement matrix represented a requirement for a particular user, the corresponding matrix element in the RSM employs the following set of numbers to represent a set of data sources. The primary sources for each requirement appear at the top of the cell in square brackets, with less important ones below in parentheses.

All sources containing any information on a particular data item are listed immediately to the right of the row heading of that item. Similarly all sources having any information required by a particular user appear directly below the column heading identifying the user. In each case, as a convention, the more important data sources are cited in square brackets at the top of the cell. The data sources are referred to by number in Table 2, as follows:

(1) IFR peak day
(2) 2% sample of filed flight plans
(3) Facility workload

  (3.1) ARTCC
  (3.2) Airport
  (3.3) FSS
  (3.4) IFSS

(4) Aircraft registration data
(5) Official Airline Guide
(6) NAS & ARTS computers
(7) Voice Tapes (FAA ATC Facilities)
(8) Weather Reports (NOAA and FAA)

Since the above sources are not adequate to satisfy all users' needs, three "pseudo-sources" have been created. The data contained in these sources are not presently available from continuing FAA collection efforts, but have been included here for completeness and to point up graphically where data gaps exist. These "pseudo-sources" and their codes in the RSM are:

	USER / DATA REQUIREMENT	DATA SOURCE	TERMINAL AREA: MLS	GROUND GUIDANCE	FREQUENCY SPECTRUM	STOL	WAKE TURBULENCE	POLLUTION	BEFORE & AFTER ARTS III
		PRIMARY DATA SOURCE	[1] [6]	[0.2] [1]	[0.2] [1]	[0.1] [6]	[0.1] [6]	[0.2] [1]	[1] [6]
		SECONDARY DATA SOURCE	(0.2) (8)	(7)(0.1)(6)	(0.1)(2)(3.1)(3.2)(5)(6)(7)	(1)(0.2)(7)(3.1)(3.2)(3.3)(5)(7)	(1)(0.2)	(6)(5)(0.1)(2)(3.2)(8)	(0.1)(2)(3.2)(0.2)(4)
GEOGRAPHICAL AREA	LARGE & MEDIUM TERMINALS	(0.1)(0.2)(1)(2)(3.2)(3.3)(3.4)(5)(6)(7)(8)	[1][6](0.2)(8)	[0.2][1](7)(0.1)(6)				[0.2][1](0.1)(2)(3.2)(5)(6)(8)	[1][6](0.1)(2)(0.2)(3.2)
GEOGRAPHICAL AREA	REPRESENTATIVE TERMINALS	(0.1)(0.2)(1)(2)(3.2)(3.3)(6)(7)(8)	(1)(6)(8)			[0.1][6](0.2)(7)(1)(3.2)(3.3)(2)	[0.1][6](1)(0.2)		
GEOGRAPHICAL AREA	NON-TOWER TERMINALS	(0.2)(2)(3.2)							
GEOGRAPHICAL AREA	LARGE HUB AREAS	(0.1)(0.2)(2)(1)(3.1)(3.2)(6)(7)			[0.2][1](2)(6)(7)(0.1)				
GEOGRAPHICAL AREA	ALL OF CONUS	(0.1)(0.2)(1)(2)(3.1)(4)(5)(6)(7)(4)							
GEOGRAPHICAL AREA	REPRESENTATIVE ENROUTE SECTOR	(0.1)(0.2)(6)(7)(1)(2)(3.1)(5)							
GEOGRAPHICAL AREA	NORTH ATLANTIC	(1)(2)(3.1)(3.4)(5)(6)(0.1)(0.2)(0.3)							
GEOGRAPHICAL AREA	U.S. COASTAL	(0.1)(0.2)(1)(2)(3.1)(3.5)([illegible])(6)(0.3)							
GEOGRAPHICAL AREA	ALL OCEANS	(0.3)([illegible])(3.4)							
TRAFFIC LEVEL DESIRED	PEAK	(0.1)(0.2)(3)(5)(6)(7)(0.3)	[1][6](0.2)	[1][0.2](7)(0.1)(6)	(0.1)[0.2][1](6)(7)		[0.1][6](0.2)(1)	[0.2][1](6)(5)	
TRAFFIC LEVEL DESIRED	AVERAGE	(0.3)(1.1)(3.2)(3.3)(3.4)(5)(2)(0.1)(6)		(0.1)(6)		[0.1][6](3.3)(3.1)(2)(5)(3.2)	[0.1][6]		[6](0.1)(2)(3.2)
TRAFFIC LEVEL DESIRED	LOW DENSITY	(0.2)(2)(3.1)(6)							
TYPE OF TRAFFIC SAMPLE	SNAPSHOT	(0.1)(6)			(0.1)(6)				[6](0.1)
TYPE OF TRAFFIC SAMPLE	INSTRUMENT APPROACHES	(1)(6)(3.1)(3.2)	[1][6]						[1][6](3.2)
TYPE OF TRAFFIC SAMPLE	TERMINAL AREA ARRIVAL RATES	(0.1)(0.2)(1)(2)(5)(6)(3.2)	[1][6](0.2)	[0.2][1](0.1)(6)		[0.1][6](1)(2)(5)(3.2)(0.2)	[0.1][6](1)(0.2)	[0.2][1](2)(0.1)(5)(6)(3.2)	
TYPE OF TRAFFIC SAMPLE	TERMINAL AREA DEPARTURE RATES	(0.1)(0.2)(1)(2)(5)(6)(3.2)		[0.2][1](0.1)(6)		[0.1][6](1)(2)(5)(3.2)(0.2)	[0.1][6](1)(0.2)	[0.2][1](2)(0.1)(5)(6)(3.2)	
TYPE OF TRAFFIC SAMPLE	GROUND OPERATION	(7)		(7)					
TYPE OF TRAFFIC SAMPLE	TRACK FLOWN	(2)(6)(0.1)							
TYPE OF TRAFFIC SAMPLE	ROUTE FLOWN	(0.1)(6)(0.3)(0.2)(2)							
TYPE OF TRAFFIC SAMPLE	ORIGIN/DESTINATION	(0.1)(0.2)(2)(5)(6)(0.3)							
TYPE OF TRAFFIC SAMPLE	INSTANTANEOUS COUNT	(0.1)(6)							
TIME LENGTH OF SAMPLE	INSTANT	(0.1)(6)			(0.1)(6)				
TIME LENGTH OF SAMPLE	MINUTE	(0.1)(6)							
TIME LENGTH OF SAMPLE	15 MINUTE	(0.1)(6)							
TIME LENGTH OF SAMPLE	HOUR	(0.2)(0.1)(6)(1)	[1][6]		[0.2][1](0.1)(6)	[0.1][6](1)(0.2)	[0.1][6](0.2)(1)		
TIME LENGTH OF SAMPLE	3 HOUR	(0.1)(0.2)(1)(6)		[0.2][1](0.1)(6)				[0.2][1](0.1)(6)	[1][6](0.1)(0.2)
TIME LENGTH OF SAMPLE	DAY	(0.1)(0.2)(1)(6)(0.3)(2)(5)						[0.2][1](0.1)(6)(2)	
TIME LENGTH OF SAMPLE	DIURNAL FLUCTUATIONS	(0.1)(2)(5)(6)		(0.1)(6)				(0.1)(2)(5)(6)	[6](0.1)(2)
	SEASONAL FLUCTUATIONS	(0.1)(3.1)(3.2)(3.4)(5)							

Table 2 - Requirements - Sources Matrix

		TERMINAL AREA						
USER		MLS	GROUND GUIDANCE	FREQUENCY SPECTRUM	STOL	WAKE TURBULENCE	POLLUTION	BEFORE & AFTER ARTS III
PRIMARY DATA SOURCE		[1][6]	[0.2][1]	[0.2][1]	[0.1][6]	[0.1][6]	[0.2][1]	[1][6]
SECONDARY DATA SOURCE		(0.2)(8)	(7)(0.1)(6)	(0.1)(2)(3.1)(3.2)(5)(6)(7)	(1)(0.2)(2)(3.1)(3.2)(3.3)(5)(7)	(1)(0.2)	(6)(5)(0.1)(2)(3.2)(8)	(0.1)(2)(3.2)(0.2)(4)
DATA REQUIREMENT	DATA SOURCE							
TRAFFIC TO BE INCLUDED: IFR ONLY	(1)(3.1)(3.4)(0.3)(3.2)(5)(6)(7)							
TRAFFIC TO BE INCLUDED: IFR & LARGE VFR	(0.2)(1)(6)(7)(2)(3.3)(3.4)(3.1)(3.2)(5)(0.1)	[1][6](0.2)			[6][0.1](0.2)(2)(3.1)(3.2)(3.3)(5)(1)(7)			[1][6](0.1)(0.2)(2)(3.2)
TRAFFIC TO BE INCLUDED: ALL TRAFFIC	(0.2)(1)(6)(7)(2)(3.3)(3.4)(0.3)(3.1)(3.2)(5)(0.1)		[1][0.2](7)(0.1)(6)	[0.2][1](7)		[0.1][6](1)(0.2)	[0.2][1](0.1)(5)(6)(2)(3.2)	
DATA REQUIRED: CATEGORY OF FLIGHT RULES IFR/VFR	(0.1)(0.2)(2)(3.3)(3.4)(0.3)							(0.1)(0.2)(2)(3.2)
USER CATEGORY AC/GA/MI	(0.1)(0.2)(3.1)(0.3)(6)(3.2)(3.3)(3.4)(2)							
FLIGHT TYPE LOCAL/ITINER.	(0.1)(3.2)(6)(0.2)							
FLIGHT DURATION	(0.2)(2)(5)(0.3)(6)(0.1)			[0.2](2)(5)(0.1)				
AIRCRAFT TYPE	(0.1)(1)(2)(4)(5)(0.2)(0.3)	[1](0.2)	[0.2][1](0.1)		[0.1](1)(0.2)(2)(5)	[0.1](0.2)(1)	[0.2][1](2)(5)(0.1)	[1](0.1)(0.2)(2)(4)
AVIONICS	(0.1)(4)(6)(0.2)	[6](0.2)		[0.2](0.1)(6)				[6](0.1)(4)(0.2)
ALTITUDE	(0.1)(1)(2)(6)(0.2)(0.3)	[1][6](0.2)			[0.1][6](1)(2)(0.2)			
SPEED	(0.1)(1)(2)(6)(0.2)	[1][6](0.2)	[0.2][1](0.1)(6)		[0.1][6](1)(2)(0.2)	[0.1][6](1)(0.2)	[0.2][1](0.1)(2)(6)	
HEADING	(0.1)(6)					[0.1][6]		
MANEUVERING	(0.1)(6)			(0.1)(6)				[6](0.1)
COMMUNICATION RATES	(6)(7)	[6]	(7)(6)	(6)(7)	[6](7)			[6]
COMMUNICATION MESSAGE LENGTH	(7)(6)			(6)(7)				[6]
SPECIAL AIRBORNE EQUIPMENT	YES/NO	YES	NO	NO	YES	NO	NO	NO

Table 2 - Requirements - Sources Matrix
(Continued)

			TERMINAL AREA CONTINUED				
	USER		ARTS III IMPLEMENTATION SCHEDULE	CAPACITY	CA	SYNCHRONOUS CABLE (MITRE)	COMMUNICATIONS REQUIREMENTS FOR RTC EQUIPMENT (CSC)
		PRIMARY DATA SOURCE	[2][3.2]	[1][0.2]	[0.1][0.2]	[0.1][6]	[0.1][6]
		SECONDARY DATA SOURCE	(1)(6)(0.1)(0.2)	(6)(0.3)	(1)(6)(2)(3.1)(3.2)(3.3)(3.4)	(1)(4)	(1)(2)(7)
	DATA REQUIREMENT	DATA SOURCE					
GEOGRAPHICAL AREA	LARGE & MEDIUM TERMINALS	(0.1)(0.2)(1)(2)(3.2)(3.3)(3.4)(5)(6)(7)(8)	[2][3.2](1)(6)(0.1)(0.2)	[0.2][1](0.1)(6)			[0.1][6](1)(2)(7)
	REPRESENTATIVE TERMINALS	(0.1)(0.2)(1)(2)(3.2)(3.3)(6)(7)(8)		[0.2][1](0.1)(6)	[0.1][0.2](1)(2)(3.2)(3.3)(6)		
	NON TOWER TERMINALS	(0.2)(2)(3.2)		[0.2]	(0.2)(2)(3.2)		
	LARGE HUB AREAS	(0.1)(0.2)(2)(1)(3.3)(3.2)(6)(7)		[0.2](6)(0.1)[1]		[0.1][6](1)	[0.1][6](1)(2)(7)
	ALL OF CONUS	(0.1)(0.2)(1)(2)(3.3)(4)(5)(6)(7)(8)					
	REPRESENTATIVE ENROUTE SECTOR	(0.1)(0.2)(6)(7)(1)(2)(3.3)(5)					
	NORTH ATLANTIC	(1)(2)(3.3)(3.4)(5)(6)(0.3)(0.2)(0.1)					
	U.S. COASTAL	(0.1)(0.2)(1)(2)(3.3)(3.4)(5)(6)(0.3)					
	ALL OCEANS	(0.3)(5)(3.4)					
TRAFFIC LEVEL DESIRED	PEAK	(0.1)(0.2)(1)(5)(6)(7)(0.3)		[1][0.2](0.1)(6)	[0.1][0.2](1)(6)	[0.1][6](1)	[0.1][6](1)(7)
	AVERAGE	(0.3)(3.1)(3.2)(3.3)(3.4)(5)(2)(0.1)(6)	[2][3.2](0.1)(6)	(0.1)(6)	[0.1](2)(6)(3.1)(3.2)(3.3)(3.4)		
	LOW DENSITY	(0.2)(2)(3.1)(6)					
TYPE OF TRAFFIC SAMPLE	SNAPSHOT	(0.1)(6)	(0.1)(6)	(0.1)(6)		[0.1][6]	[0.1][6]
	INDEPENDENT APPROACHES	(1)(6)(3.1)(3.2)	(1)(6)[3.2]				[6](1)
	TERMINAL AREA ARRIVAL RATES	(0.1)(0.2)(1)(2)(5)(6)(3.2)		[1][0.2](0.1)(6)	[0.1][0.2](1)(2)(6)(3.2)		
	TERMINAL AREA DEPARTURE RATES	(0.1)(0.2)(1)(2)(5)(6)(3.2)		[1][0.2](0.1)(6)	[0.1][0.2](1)(2)(6)(3.2)		
	GROUND OPERATION	(7)					(7)
	TRACK FLOWN	(2)(6)(0.1)					
	ROUTE FLOWS	(0.1)(6)(0.3)(0.2)(2)					
	ORIGIN/DESTINATION	(0.1)(0.2)(2)(5)(6)(0.3)					
	INSTANTANEOUS COUNT	(0.1)(6)					
TIME LENGTH OF SAMPLE	INSTANT	(0.1)(6)				[0.1][6]	[0.1][6]
	MINUTE	(0.1)(6)					[0.1][6]
	15 MINUTE	(0.1)(6)					[0.1][6]
	HOUR	(0.2)(0.1)(6)(1)		[1][0.2](0.1)(6)	[0.1][0.2](1)(6)		
	3 HOUR	(0.1)(0.2)(1)(6)	(1)(6)(0.1)(0.2)	[1][0.2](0.1)(6)	[0.1][0.2](1)(6)		
	DAY	(0.1)(0.2)(1)(6)(0.3)(2)(5)					
	DIURNAL FLUCTUATIONS	(0.1)(2)(5)(6)	[2](0.1)(6)	(0.1)(6)	[0.1](2)(6)		[0.1][6](2)
	SEASONAL FLUCTUATIONS	(0.1)(3.1)(3.2)(3.3)(3.4)(5)			[0.1](3.1)(3.2)(3.3)(3.4)		(0.1)(5)

Table 2 - Requirements - Sources Matrix (Continued)

		TERMINAL AREA CONTINUED				
USER		ARTS III IMPLEMENTATION SCHEDULE	CAPACITY	GA	SYNCHRONOUS GARBLE (MITRE)	COMMUNICATIONS REQUIREMENTS FOR UTG EQUIPMENT (CSC)
PRIMARY DATA SOURCE		[2][3.2]	[1][0.2]	[0.1][0.2]	[0.1][6]	[0.1][6]
SECONDARY DATA SOURCE		(1)(6)(0.1)(0.2)	(6)(0.1)	(1)(6)(2)(3.1)(3.2)(3.3)(3.4)	(1)(4)	(1)(2)(7)
DATA REQUIREMENT	DATA SOURCE					
TRAFFIC TO BE INCLUDED: IFR ONLY	(1)(3.1)(3.4)(0.3)(3.2)(5)(6)(7)					
IFR & LARGE VFR	(0.2)(1)(6)(7)(2)(3.3)(3.4)(3.1)(3.2)(5)(0.1)	[2][3.2](1)(0.2)(6)(0.1)				
ALL TRAFFIC	(0.2)(1)(6)(7)(2)(3.3)(3.4)(0.3)(3.1)(3.2)(5)(0.1)		[1][0.2](0.1)(6)	[0.1][0.2](1)(6)(2)(3.1)(3.2)(3.3)(3.4)	[0.1][6](1)	[0.1][6](1)(2)(7)
DATA REQUIRED: CATEGORY OF FLIGHT RULES IFR/VFR	(0.1)(0.2)(2)(3.3)(3.4)(0.3)	[2](0.1)(0.2)	[0.2](0.1)	[0.1][0.2](2)(3.3)(3.4)		
USER CATEGORY AC/GA/MI	(0.1)(0.3)(3.1)(0.3)(6)(3.2)(3.3)(3.4)(2)	[2](0.1)(0.2)[3.2] (6)		[0.1][0.2](2)(3.1)(3.2)(3.3)(3.4)(6)		
FLIGHT TYPE LOCAL ITINERANT	(0.1)(3.2)(6)(0.2)	[3.2](0.1)(0.2)(6)	[0.2](0.1)(6)	[0.1][0.2](3.2)(6)		
FLIGHT DURATION	(0.2)(2)(5)(0.3)(6)(0.1)		[0.2](6)(0.1)	[0.2](2)[0.1]		
AIRCRAFT TYPE	(0.1)(1)(2)(4)(5)(0.2)(0.3)	[2](0.1)(0.2)(1)	[1][0.2](0.1)	[0.1][0.2](1)(2)		[0.1](1)(2)
AVIONICS	(0.1)(4)(6)(0.2)	(0.1)(0.2)(6)		[0.1][0.2](6)	[0.1][6](4)	[0.1][6]
ALTITUDE	(0.1)(1)(2)(6)(0.2)(0.3)		[1][0.2](0.1)(6)	[0.1][0.2](2)(6)		[0.1][6](1)(2)
SPEED	(0.1)(1)(2)(6)(0.2)		[1][0.2](0.1)(6)	[0.1][0.2](1)(2)(6)		[0.1][6](1)(2)
HEADING	(0.1)(6)		(0.1)(6)			[0.1][6]
MANEUVERING	(0.1)(6)					
COMMUNICATION RATES	(6)(7)		(6)			[6](7)
COMMUNICATION MESSAGE LENGTH	(7)(6)		(6)			[6](7)
SPECIAL AIRBORNE EQUIPMENT	YES/NO	NO	NO	NO	NO	YES

Table 2 - Requirements - Sources Matrix
(Continued)

	USER		ENROUTE AREA						
			CAS (TIME)	BEFORE & AFTER NAS STAGE A	CAPACITY	SIZING NAS COMPUTERS (MITRE)	COMMUNICATIONS REQUIREMENTS FOR UTG EQUIPMENT (CSC)	IFF/EMC INTERFERENCE (ECAC)	RNAV
	PRIMARY DATA SOURCE		[0.1][6]	[1][6]	[0.2][1]	[6]	[0.1][6]	[0.1][6]	[1][0.2]
	SECONDARY DATA SOURCE		(1) (2) (3.1) (3.2) (3.3) (3.4) (0.2) (5)	(0.1) (2) (3.3) (0.2) (4)	(0.1) (6)	(1) (0.1) (0.2)	(0.2) (1) (2) (7)		(0.1) (2) (5) (8) (6)
	DATA REQUIREMENT	DATA SOURCE							
GEOGRAPHICAL AREA	LARGE & MEDIUM TERMINALS	(0.1) (0.2) (1) (2) (3.2) (3.3) (3.4) (5) (6) (7) (8)							
	REPRESENTATIVE TERMINALS	(0.1) (0.2) (1) (2) (3.2) (3.3) (6) (7) (8)							
	NON-TOWER TERMINALS	(0.2) (2) (3.2)							
	LARGE HUB AREAS	(0.1) (0.2) (2) (1) (3.1) (3.2) (6) (7)							
	ALL OF CONUS	(0.1) (0.2) (1) (2) (3.1) (4) (5) (6) (7) (8)	[0.1] [6] (1) (2) (3.1) (0.2) (5)			[6] (1) (0.1) (0.2)		[0.1] [6]	[1] [0.2] [0.1] (2) (5) (8) (6)
	REPRESENTATIVE ENROUTE SECTOR	(0.1) (0.2) (6) (7) (1) (2) (3.1) (4)		[1] [6] (0.1) (0.2) (2) (4)	[0.2] [1] (0.1) (6)	[6] (1) (0.1) (0.2)	[0.1] [6] (1) (2) (0.2) (7)		
	NORTH ATLANTIC	(1) (2) (3.1) (3.4) (5) (6) (0.1) (0.2) (0.3)							
	U.S. COASTAL	(0.1) (0.2) (1) (2) (3.1) (3.4) (5) (6) (0.3)							
	ALL OCEANS	(0.3) (5) (3.4)							
TRAFFIC LEVEL DESIRED	PEAK	(0.1) (0.2) (1) (5) (6) (7) (0.3)			[0.2] [1] (0.1) (6)	[6] (1) (0.1) (0.2)	[0.1] [6] (0.2) (1) (7)	[0.1] [6]	[1] [0.2] (0.1) (5) (6)
	AVERAGE	(0.3) (3.1) (3.2) (3.3) (3.4) (5) (2) (0.1) (6)		[6] (0.1) (2) (3.3)	(0.1) (6)				(0.1) (2) (5) (6)
	LOW DENSITY	(0.2) (2) (3.1) (6)	[6] (0.2) (2) (3.1)						
TYPE OF TRAFFIC SAMPLE	SNAPSHOT	(0.1) (6)	[0.1] [6]	[6] (0.1)	(0.1) (6)	[6] (0.1)	[0.1] [6]	[0.1] [6]	
	INSTRUMENT APPROACHES	(1) (6) (3.1) (3.2)							
	TERMINAL AREA ARRIVAL RATES	(0.1) (0.2) (1) (2) (5) (6) (3.2)							
	TERMINAL AREA DEPARTURE RATES	(0.1) (0.2) (1) (2) (5) (6) (3.2)							
	GROUND OPERATION	(7)							
	TRACK FLOWS	(2) (6) (0.1)			(6) (0.1)			[0.1] [6]	
	ROUTE FLOWS	(0.1) (6) (0.3) (0.2) (2)			[0.2] (0.1) (6)				[0.2] (0.1) (2) (6)
	ORIGIN/DESTINATION	(0.1) (0.2) (2) (5) (6) (0.3)							[0.2] (0.1) (2) (5) (6)
	INSTANTANEOUS COUNT	(0.1) (6)				[6] (0.1)	[0.1] [6]		
TIME LENGTH OF SAMPLE	INSTANT	(0.1) (6)	[0.1] [6]			[6] (0.1)	[0.1] [6]		
	MINUTE	(0.1) (6)				[6] (0.1)	[0.1] [6]		
	15 MINUTE	(0.1) (6)					[0.1] [6]		
	HOUR	(0.2) (0.1) (6) (1)			[0.2] [1] (0.1) (6)			[0.1] [6]	
	3 HOUR	(0.1) (0.2) (1) (6)		[1] [6] (0.1) (0.2)	[0.2] [1] (0.1) (6)				
	DAY	(0.1) (0.2) (1) (6) (0.3) (2) (5)						[0.1] [6]	[1] [0.2] (1) (2) (6)
	DIURNAL FLUCTUATIONS	(0.3) (2) (5) (6)			(0.1) (6)	[6] (0.1)	(0.1) [6] (2)		(0.1) (2) (5) (6)
	SEASONAL FLUCTUATIONS	(0.1) (3.1) (3.2) (3.3) (3.4) (5)							

Table 2 - Requirements - Sources Matrix (Continued)

		ENROUTE AREA CONTINUED						
	USER	CAS (TIME)	BEFORE & AFTER NAS STAGE A	CAPACITY	SIZING NAS COMPUTERS (MITRE)	COMMUNICATIONS REQUIREMENTS FOR UTG EQUIPMENT (CSC)	IFF/EMC INTERFERENCE (ECAC)	RNAV
	PRIMARY DATA SOURCE	[0.1][6]	[1][6]	[0.2][1]	[6]	[0.1][6]	[0.1][6]	[1][0.2]
	SECONDARY DATA SOURCE	(1)(2)(3.1)(3.2)(3.3)(3.4)(0.2)(5)	(0.1)(2)(3.3)(0.2)(4)	(0.1)(6)	(1)(0.1)(0.2)	(0.2)(1)(2)(7)		(0.1)(2)(5)(8)(6)
DATA REQUIREMENT	DATA SOURCE							
TRAFFIC TO BE INCLUDED: IFR ONLY	(1)(3.1)(3.4)(0.3)(3.2)(5)(6)(7)				[6](1)			
TRAFFIC TO BE INCLUDED: IFR & LARGE VFR	(0.2)(1)(6)(7)(2)(3.3)(3.4)(3.1)(3.2)(5)(0.1)		[1][6](0.1)(0.2)(2)(3.3)					[1][0.2](0.1)(2)(5)(6)
TRAFFIC TO BE INCLUDED: ALL TRAFFIC	(0.2)(1)(6)(7)(2)(3.3)(3.4)(0.3)(3.1)(3.2)(5)(0.1)	[0.1][6](1)(2)(3.1)(3.2)(3.3)(3.4)(5)(0.2)		[0.2][1](0.1)(6)	[6](1)(0.1)(0.2)	[0.1][6](0.2)(1)(2)(7)	[0.1][6]	
DATA REQUIRED: CATEGORY OF FLIGHT RULES IFR/VFR	(0.1)(0.2)(2)(3.3)(3.4)(3)		(0.1)(0.2)(2)(3.3)	[0.2](0.1)	(0.1)(0.2)			[0.2](0.1)(2)
USER CATEGORY AC/GA/MI	(0.1)(0.3)(3.1)(0.3)(6)(3.2)(3.3)(3.4)(2)	[0.1][6]			[6](0.1)(0.2)			[0.2](0.1)(2)(6)
FLIGHT TYPE LOCAL/ITINERANT	(0.1)(3.2)(6)(0.2)			[0.2](0.1)(6)				[0.2](0.1)(6)
FLIGHT DURATION	(0.2)(2)(5)(0.3)(6)(0.1)			[0.2](6)(0.1)				[0.2](2)(5)(6)(0.1)
AIRCRAFT TYPE	(0.1)(1)(2)(4)(5)(0.2)(0.3)			[0.2][1](0.1)	(1)(0.1)(0.2)	[0.1](0.2)(1)(2)		[1][0.2](0.1)(2)(5)
AVIONICS	(0.1)(4)(6)(0.2)	[0.1][6](0.2)	[6](0.1)(0.2)(4)		[6](0.1)(0.2)	[0.1][6](0.2)	[0.1][6]	[0.2](0.1)(6)
ALTITUDE	(0.1)(1)(2)(6)(0.2)(0.3)			[0.2][1](0.1)(6)	[6](1)(0.1)(0.2)	[0.1][6](2)(1)(0.2)	[0.1][6]	[1][0.2](0.1)(2)(6)
SPEED	(0.1)(1)(2)(6)(0.2)			[0.2][1](0.1)(6)		[0.1][6](0.2)(1)(2)	[0.1][6]	[0.2][1](0.1)(2)(6)
HEADING	(0.1)(6)			(0.1)(6)			[0.1][6]	
MANEUVERING	(0.1)(6)		[6][0.1]	(0.1)(6)		[0.1][6]	[0.1][6]	
COMMUNICATION RATES	(6)(7)		[6]	(6)	[6]	[6](7)		
COMMUNICATION MESSAGE LENGTH	(7)(6)		[6]	[6]		[6](7)		
SPECIAL AIRBORNE EQUIPMENT	YES/NO	YES	NO	NO	NO	YES	NO	YES

Table 2 - Requirements - Sources Matrix
(Continued)

	USER		ENROUTE AREA CONTINUED		OCEANIC AREA			
			TACAN & DME (ECAC)	FREQUENCY ASSIGNMENT FOR ENROUTE SECTORS (ECAC)	OMEGA	SIZING NAS COMPUTERS OCEANIC SECTORS (MITRE)	FIR RECONFIGURATION (CSC)	SATELLITE NAVIGATION POWER REQUIREMENTS (CSC)
		PRIMARY DATA SOURCE	[0.1][6]	[0.1][6]	[0.3][5]	[0.3][5]	[0.3][5]	[0.3][5]
		SECONDARY DATA SOURCE	(4)	(7)	(2)(3.4)	(1)(6)	(1)(2)(3.4)	(2)(3.4)
	DATA REQUIREMENT	DATA SOURCE						
GEOGRAPHICAL AREA	LARGE & MEDIUM TERMINALS	(0.1)(0.2)(1)(2)(1.2)(3.1((3.4)(5)(6)(7)(8)						
	REPRESENTATIVE TERMINALS	(0.1)(0.2)(1)(2)(1.2)(3.1)(6)(7)(8)						
	NON-TOWER TERMINALS	(0.2)(2)(3.2)						
	LARGE HUB AREAS	(0.1)(0.2)(2)(1)(3.1)(3.2)(6)(7)						
	ALL OF CONUS	(0.1)(0.2)(1)(2)(3.1)(4)(5)(6)(7)(8)		[0.1][6] (7)				
	REPRESENTATIVE ENROUTE SECTOR	(0.1)(0.2)(6)(7)(1)(2)(3.1)(4)	[0.1][6[(4)					
	NORTH ATLANTIC	(1)(2)(3.1)(1.4)(5)(6)(0.1)(0.2)(0.3)					[0.3][5](1)(2)(1.4)	[0.3][5](2)(1.4)
	U.S. COASTAL	(0.1)(0.2)(1)(2)(3.1)(3.4)(5)(6)(0.3)				[0.3][5[(1)(6)		
	ALL OCEANS	(0.3)(5)(3.4)			[0.3][5[(3)(4)			
TRAFFIC LEVEL DESIRED	PEAK	(0.1)(0.2)(1)(5)(6)(7)(0.3)	[0.1][6[(4)	[0.1][6](7)		[0.3][5] (1)(6)	[0.3][5] (1)	[0.3][5]
	AVERAGE	(0.3)(3.1)(1.2)(3.3)(3.4)(5)(2)(0.1)(6)			[0.3][5] (2)(3.4)			
	LOW DENSITY	(0.2)(2)(3.1)(6)						
TYPE OF TRAFFIC SAMPLE	SNAPSHOT	(0.1)(6)	[0.1][6]					
	INSTRUMENT APPROACHES	(1)(6)(3.1)(3.2)						
	TERMINAL AREA ARRIVAL RATES	(0.1)(0.2)(1)(2)(5)(6)(3.2)						
	TERMINAL AREA DEPARTURE RATES	(0.1)(0.2)(1)(2)(5)(6)(3.2)						
	GROUND OPERATION	(7)						
	TRACK FLOWN	(2)(6)(0.1)						
	ROUTE FLOWN	(0.1)(6)(0.3)(0.2)(2)			[0.3](2)			
	ORIGIN/DESTINATION	(0.1)(0.2)(2)(5)(6)(0.3)			[0.3][5] (2)		[0.3][5](2)	
	INSTANTANEOUS COUNT	(0.1)(6)		[0.1][6]				
TIME LENGTH OF SAMPLE	INSTANT	(0.1)(6)	[0.1][6[	[0.1][6]		(6)		
	MINUTE	(0.1)(6)				(6)		
	15 MINUTE	(0.1)(6)						
	HOUR	(0.2)(0.1)(6)(1)						
	3 HOUR	(0.1)(0.2)(1)(6)						
	DAY	(0.1)(0.2)(1)(6)(0.3)(2)(5)			[0.3][5](2)		[0.3][5](2)(1)	[0.3][5](2)
	DIURNAL FLUCTUATIONS	(0.1)(2)(5)(6)				[5](6)	[5](2)	[5[(2)
	SEASONAL FLUCTUATIONS	(0.1)(3.1)(3.2)(3.3)(3.4)(5)			[5](3.4)		(5)(3.4)	

Table 2 - Requirements - Sources Matrix

(Continued)

			ENROUTE AREA CONTINUED		OCEANIC AREA			
	USER		TACAN & DME (ECAC)	FREQUENCY ASSIGNMENT FOR ENROUTE SECTORS (ECAC)	OMEGA	SIZING NAS COMPUTERS OCEANIC SECTORS (MITRE)	FIR RECON-FIGURATION (CSC)	SATELLITE NAVIGATION POWER REQUIREMENTS (CSC)
		PRIMARY DATA SOURCE	[0.1][6]	[0.1][6]	[0.3][5]	[0.3][5]	[0.3][5]	[0.3][5]
		SECONDARY DATA SOURCE	(4)	(7)	(2)(3.4)	(1)(6)	(1)(2)(3.4)	(2)(3.4)
	DATA REQUIREMENT	DATA SOURCE						
TRAFFIC TO BE INCLUDED	IFR ONLY	(1)(3.1)(3.4)(0.3) (3.2)(5)(6)(7)		[6]	[5][0.3]	[5](6)(1) [0.3]	[0.3][5](1) (3.4)	[0.3][5] (3.4)
	IFR & LARGE VFR	(0.2)(1)(6)(7) (2)(3.3)(3.4) (3.1)(3.2)(5)(0.1)						
	ALL TRAFFIC	(0.2)(1)(6)(7) (2)(3.3)(3.4)(0.3) (3.1)(3.2)(5)(0.1)	[0.1][6]			[0.3][5] (1)(6)		
DATA REQUIRED	CATEFORY OF FLIGHT RULES IFR/VFR	(0.1)(0.2)(2) (3.3)(3.4)(3)				[0.3]		
	USER CATEGORY AG/GA/MI	(0.1)(0.3)(3.1) (0.3)(6) (3.2)(3.3)(3.4)(2)			(2)(3.4)[0.3]	(6)[0.3]		
	FLIGHT TYPE LOCAL/ITINERANT	(0.1)(3.2)(6) (0.2)						
	FLIGHT DURATION	(0.2)(2)(5) (0.3)(6)(0.1)		[0.1][6]	[0.3][5] (2)		[0.3][5] (2)	
	AIRCRAFT TYPE	(0.1)(1)(2)(4) (5)(0.2)(0.3)	[0.1]		[0.3][5] (2)	[0.3][5](1)		
	AVIONICS	(0.1)(4)(6) (0.2)	[0.1][6](4)	[0.1][6]	[0.3]	[0.3](6)		[0.3]
	ALTITUDE	(0.1)(1)(2) (6)(0.2)(0.3)	[C.1][6]	[0.1][6]	[0.3](2)	[0.3](1)(6)		
	SPEEO	(0.1)(1)(2) (6)(0.2)	[0.1][6]					
	HEADING	(0.1)(6)						
	MANEUVERING	(0.1)(6)						
	COMMUNICATION RATES	(6)(7)		[6](7)		(6)		
	COMMUNICATION MESSAGE LENGTH	(7)(6)		[6](7)				
	SPECIAL AIRBORNE EQIPMENT	YES/NO	YES	NO	YES			YES

Table 2 - Requirements - Sources Matrix
(Continued)

(0.1) VFR tracking data

Contents: Position (x, y, z), class of user, type of aircraft, O/D, IFR/VFR classification, local/itinerant, avionic instruments. (Data accumulated every few seconds or few minutes.)

(0.2) VFR peak day data (corresponds to IFR peak day data). Contents: class of user, type of aircraft, route flown, O/D, IFR/VFR classification, local/itinerant, duration, speed, altitude and avionic instruments.

(0.3) Non-AC Trans-oceanic peak day data. Contents: Class of user, type of aircraft, route flown, O/D, IFR/VFR classification, speed, altitude, and avionic instruments.

4.3 <u>Data Not Now Available From Continuing FAA Data Collection Efforts</u>

Current FAA continuing data collection efforts do not include data in the following categories:

1. VFR traffic not filing a flight plan,
2. Instantaneous positions of aircraft,
3. Avionics usage as distinguished from the fraction of aircraft equipped,
4. Departure and arrival time distributions for all flights as well as the actual arrival time of any given flight,
5. Positions or tracks of oceanic flights (track data will soon be available from NAS computer output for IFR flights over CONUS).

The most critical lack of data for FAA planning efforts pertains to VFR flights, since many policy decisions can be affected by these flights, now of only peripheral interest to the ATC system. Since data on VFR flights are difficult to obtain, the needs for such data and possible ways of obtaining them are discussed more fully in section 4.3.1 below.

The lack of instantaneous position data stems from the fact that most FAA continuing data efforts were designed primarily to collect workload data for planning personnel assignments and other day to day operations. Most of the current data consist of monthly or yearly summaries, so that peaking characteristics disappear and events which occur relatively infrequently, but which have great effect on the system (e.g., accidents, very heavy fog, equipment failure), are lost among the averaged data. Some of this lack of instantaneous position data will be remedied when the tracking programs become operational as part of the NAS computer system. Some were scheduled to be operational at certain ARTCC's in 1973. Even with the data from the NAS system, only IFR aircraft will be tracked and therefore the lack of data on VFR tracks will continue.

The accomplishment of some studies depends on knowing what fraction of the aircraft airborne at any one instant are using a particular type of avionics equipment (e.g., beacon transponder, VOR, DME, RNAV, radio on each frequency, etc.). The aircraft registration records contain data on the type of equipment installed in the aircraft but provide no indication of usage. The frequency of use might be approximated by assuming that it is proportional to hours flown, which is included in the registration records. However, such data are too highly aggregated to be useful for assessing peak loads on various navigation and communications systems. Better information on equipment usage under various specific conditions is needed, and this must be tied to the instantaneous data requirements previously discussed.

Departure and arrival time data have serious gaps. Departure times, both requested and actual, are recorded for all IFR flights. The CATER program in operation at the three New York area airports (LGA, EWR and JFK) records departure times for <u>all</u> flights; similar data are potentially available from many FAA towers with a comparatively minimal data collection effort, and comparable efforts might collect such data at many airports. Arrival time data are not now recorded. Flight strips do not presently include these data, and future ARTS computer systems will send only a drop track message to the NAS computers <u>about</u> 2 miles from touchdown. More accurate arrival time distribution data are, of course, potentially collectable in a manner similar to that used for recording departure times. The single set of arrival time data most difficult to obtain consists of the touchdown times for specific flights so that, for instance, the peak day flight information would contain both departure and arrival times.

One more area where data are critically lacking concerns positions and tracks of oceanic flights. Since there is currently no surveillance system for such flights, actual positions and tracks are unknown. It does not seem that this will change greatly in the near future, unless some surveillance system which can provide complete oceanic coverage (perhaps using satellites) is established.

The most critical data lack, as discussed above, is the lack of any data on most VFR flights. This situation will therefore be discussed in greater detail below.

4.3.1 Why Are Data on VFR Flights Needed?

Considering the difficulty of obtaining data on VFR flights and the fact that the system has managed without them until now, one might well ask whether these data are really needed. The answer is strongly affirmative, and the need is becoming more sophisticated. Several underlying reasons are discussed below.

In the first place, VFR flights form a substantial (but unknown) fraction of all flights. Although VFR traffic may comprise up to four fifths of all aircraft operations at flight terminals in the United States, very little information exists on which to base an accurate estimate of the actual number of VFR flights, their distribution by geographical area or time interval, total number of hours flown, or the net impact of this traffic on the ATC system.

In fact, the four fifths cited above is a very rough approximation derived from the fraction of VFR traffic in the 2% sample of filed flights plans for 1967-71, and the number of aircraft contacted in 1969. It is further realized that these data will not yield a precise estimate of the VFR/IFR mix since most air carrier flights, which are still the predominant IFR users, file directly through the ARTCC's. On the other hand, the FAA air traffic activity counts include only those operations which come in contact with or use FAA ATC facilities or services. These facilities and services are either available or readily accessible at perhaps something less than 20% of the nation's almost 11,000 airports, leaving completely unaccounted for what could be a substantial portion of all VFR operations.

A second reason for collecting data on VFR flights is that many of these flights impinge on the control environment, and thus affect the ATC system. Three areas in which this occurs are voice communications, particularly those involving advisory services, terminal operations (these two constituting activities in which VFR flights "compete for the available resources"), and radar detection and tracing by primary returns, in which uncontrolled aircraft (VFR traffic) become "bogeys", i.e., clutter and noise which degrade radar performance. In the past, actual encroachment of VFR traffic on control activities has been relatively small. However, because of recent expansion of controlled airspace where VFR flights are required to operate under air traffic control (such as TCA's) and the increasing use of transponders in general aviation aircraft, VFR operations have become more visible to the ATC system.

VFR flights also affect system capacity. The local effects of expansion of control have generally been a decrease in VFR traffic, some of which is diverted to other areas, and an increase in IFR operations, some of which represents shifts in flight mode by pilots who heretofore have flown VFR. In consequence, the contribution of current VFR traffic to future saturation may not always be apparent.

Finally, data are needed on VFR traffic because such traffic utilizes the same navigation and communications facilities as do IFR flights. Two clear examples are DME and beacon transponders, both of which are only moderately expensive to install in aircraft, are under consideration as possible mandatory equipment, are used by both VFR and IFR traffic, and whose use is subject to capacity or saturation limita--tions. Too many aircraft operations with DMEs or transponders in the same area can create electromagnetic interference problems and degrade the ATC system. In addition, the assignment of discrete transponder codes could become a problem because the available number of codes is fixed.

There appears to be a tendency for VFR and IFR traffic to become progressively more segregated from each other. An example is the regulatory altitude limitation excluding VFR traffic from the Positive Control Airspace high altitude structure. In general, the increasing segregation has indirect causes, and the present degree of separation is not known precisely. If segregation should become virtually total in the future, then VFR data would clearly not be essential to the analysis of IFR traffic problems. The possibility that future IFR/VFR interaction may be reduced is suggested by the indicators of growth if VFR traffic. While these indicators continue to be positive, the rates of increase have diminished. At the same time, the rate of growth in GA IFR flying is increasing at a level which more than compensates for the decrease in VFR activity. This suggests a leveling off in the volume of future VFR traffic, which may therefore be amenable to being "contained in more limited airspace."

Some recognized causes of the trend toward geographical separation of IFR and VFR traffic can be cited. One is a growing tendency to impose landing fees at large terminals, thus discouraging use by privately owned, small aircraft which constitute the bulk of VFR traffic. Another is the establishment of air traffic control towers (even VFR towers) at moderate activity airports; it has been noted that these drive away two activity classes which account for substantial non-filed VFR traffic, namely flight schools and recreational flyers. Also, as previously mentioned, the expansion of the airspace where VFR users are required to operate under control has encouraged the more serious users to convert to IFR operations. Further evidence for the existence of the separation is seen in the fact that fewer than half (12) of the 25 terminals in the U.S. with the largest number of IFR flight plans filed in 1969 were also in the high 25 for filed VFR flight plans. Moreover, of the FSS's which contacted the largest number of IFR flights, only 5 were in the high 25 for VFR operations. It might then be concluded from these observations that separation between non-filing VFR flights and IFR flights in "busy" areas is greater than the filed VFR/IFR split, but because of the minimal interface of IFR operations with FSS's, more evidence would be desirable.

A typical characteristic of VFR flights is the general absence (except in the vicinity of an airport) of other air traffic visible to the pilot or passengers throughout the duration of cross-country trips, even when traversing the busier VOR airways. With the increased use of RNAV, the same conditions would presumably continue to occur in spite of any possible increase in air activity over, say, a five-year period.

On balance, the arguments for requiring VFR data outweigh those against, since the continuing lack of such data leaves most information on the impact of VFR traffic in the realm of supposition and conjecture.

4.3.2 Forecasting VFR Traffic

Accurate forecasts of the growth of VFR traffic are difficult because of the lack of present data. This is so especially because growth may be determined to a great extent by FAA and Congressional policies and such other factors as the availability of fuel for non-essential travel.

The general aviation community and some analysts recognize that progressive increases in user charges, avionics requirements, fuel shortages, and further restrictions by extension of controlled airspace could eventually eliminate GA, except for some business operations. Despite this possibility, it is believed that the short term consequence will be a leveling off or decrease in VFR flights, and a continuing expansion of IFR operations. Much of the pilot population is probably willing to accept some increased ATC requirements along with a reasonable increase in operating costs in return for higher aircraft utilization and the navigational and safety benefits of instrument flight. This implies that projections of future IFR traffic must include estimates of this conversion, as well as growth which is "externally" induced.

Based on studies conducted in the sixties, aviation traffic analysts generally believe that filed VFR flight plans represent about 1/7 of all VFR flights. No recent efforts to validate this estimate came to light during our study. VFR flight plans accounted for about 40% of all those filed at FSS's, IFSS's, and CS/T's according to the 2% sample in 1972. Assuming that about 1/2 of all IFR flight plans are covered by the sample (the remainder, almost exclusively air carrier flights, having been filed directly through ARTCC's), a crude approximation of the VFR percentage of total flights is given by:

$$\frac{7 \times .4}{.6 + .6 + 7 \times .4} \times 100 = 70\%$$

It is problematical whether this estimate can be refined without massive expenditures. The CATER program, instituted in connection with studies of noise abatement, undertook to record and store for analysis all operations at five major airports: LGA, EWR, JFK, ORD, and DCA. To date, the program has been operative only at the three New York terminals. It could be expanded to include operations at a variety of moderately large terminals representative of different areas. However, the traffic originating at small airports, particularly non-tower terminals, would still go unrecorded.

"Aircraft contacted" data from the 1970 FAA Statistical Handbook of Aviation [12] show that VFR flights accounted for about 8.6 million out of 9.9 million total contacts by Flight Service Stations, or about 87%. The corresponding figures for GA are 7.8 million out of 8.4 million, or about 91%. These percentages are of particular significance because the data are not limited to filed flights, but include flights which had no other contact with the FAA's ATC facilities or services. Therefore, unlike the 2% sample (which records only arrivals and departures), they give some indication of the VFR/IFR in-flight ratio over time. However, they are subject to two immediately identifiable distorting factors: 1) IFR and filed VFR flights are likely to be airborne for a longer time period than are unfiled VFR flights, and so may represent more contacts per flight, and 2) IFR and filed VFR flights may request and receive advisories from other ATC facilities, such as ARTCC's.

Using hours flown data from the FAA Statistical Handbook (1970) [12], it is possible to make crude estimates indicating that about 80% of GA traffic (measured in hours flown) is VFR, if it is assumed that all Business and Executive flights are IFR and all other GA flights are VFR. Such crude estimates are shown in the following table:

	Hours	%
Business & Executive	5,324,000	21.1
Personal	7,694,000	30.5
Instructional	6,826,000	27.1
Aerial Application	1,427,000	5.7
Air Taxi	2,238,000	8.9
Other	1,711,000	6.8

As mentioned elsewhere in this report, instantaneous distributions (snapshot) of IFR and some filed VFR traffic in the airspace could be approximated by collecting flight strips from ATC facilities. No such process is available for supplementing IFR snapshots with distributions of VFR traffic.

If instantaneous snapshots of total air traffic are required for the analysis of an ATC system, and if adequate simulations cannot be designed to use existing data sources, then a suggested pilot questionnaire, which is more fully discussed in Section 5.1.2, is one possible avenue to obtaining the snapshot data.

5.0 DATA SETS TO SATISFY USER REQUIREMENTS

In the early stages of this study it was hoped that a single set of data might satisfy all users. It soon became clear that user requirements differ enough that data collection efforts could be most efficiently designed around five separate data sets based on the subsystem of the air traffic control system on which the data are focussed (terminal, en route or oceanic) and the type of data sample required (snapshot, operation counts, origin/destination data, or instantaneous counts).

It may be instructive to examine some of the considerations which indicate the infeasibility of a single data file for the desired data sets. The spectrum of data requirements for ATC analyses could, in principle, be satisfied by a file containing tracks of all flights in the U.S. for a single year if the following conditions are all satisfied: (a) any requirements for meteorological, electromagnetic radiation, or other non-aircraft data are disregarded; (b) traffic outside CONUS is ignored; (c) all flight data for a full year can indeed be recorded, which is not at all likely; and (d) growth factors are well enough known to permit projection of detailed flight activity from one year to another (which is even less likely than acquiring the historical data). Given this hypothetical file, users would be able to extract data relevant to their analyses, albeit at considerable software cost. It may be conservatively estimated that CONUS flights now total 60 million annually. Assuming an average flight duration of 30 minutes and a 2-second data recording interval, there would be an average of 450 data points per track. This necessitates a storage capacity for 70 million flight track data "blocks" per day, an overwhelming mass of data even with current advanced information processing technology. As a result 5 separate data sets (described below) are proposed to satisfy user requirements.

The proposed data sets will be based on traffic data current for the year of collection and on forecasted traffic levels for a ten-year horizon (perhaps with some intermediate points). The following section provides, for each contemplated data set: a description of the contents, a discussion of methods by which the data may be obtained, forecasting requirements and possible procedures for meeting them and a discussion of how the data set meets the requirements of each anticipated user of the set. Before discussing these five sets, some general observations on forecasting air traffic data are in order.

Any approach to the formulation of air traffic activity forecast requirements must consider what might happen to the general aviation fleet. In fact, since GA represents approximately 97% of the total civil aircraft fleet, it could be the major concern of the forecast effort. The future growth or decline of the GA fleet could be directly tied to user charge legislation. For example, if severe user charges are levied on aircraft owners, GA could be virtually eliminated. The expected increase in the amount of GA IFR traffic (e.g., more executive jets) might cause a considerable change in the makeup and ATC requirements of the GA fleet. These and other factors affecting GA must be considered in detail during investigations into forecast requirements.

The amount and kinds of avionics equipment to be installed and the level of use are certainly difficult to forecast, although a number of methods have been suggested. One method relies on information gleaned from market analyses performed by manufacturers. A simpler technique would apply previously observed rates of introduction of comparable equipment. A variation would be an analysis of cost variation over time to estimate how soon the price of a piece of equipment decreases to a level "reachable" by the general flying public. On the other hand, the installation of avionics equipment may not lend itself to this type of forecast analysis, its history perhaps suggesting only a reaction to FAA's regulations and other actions requiring or encouraging such installation.

Attempting to forecast the amount of usage of avionics equipment leads rapidly into the realm of FAA procedures changes. If, for example, it is required that all aircraft entering or leaving a terminal control area have and use a particular piece of avionics equipment, the usage figures will reflect that requirement. However, it is very difficult to predict changes in procedures, hence it is not unusual to assume simply that procedures remain the same, which is unrealistic. Forecasts of altitude and speed distributions utilize forecasts of aircraft type mix since optimal cruising altitude and speed depend on aircraft performance characteristics and ATC personnel accede to pilot requests whenever possible. Although forecasts of altitude and speed are published for hub areas, they are not made for specific terminals. Unless the data and forecasting procedures permit such localized forecasts, alternative techniques must be developed.

Air traffic forecasts must also take into account, in some manner, changes in the existing air route structure. Modifications to existing routes, additions of new routes or the introduction of RNAV routes must all be considered. In the first two cases, it may be possible to redistribute the traffic since the changes are known. With RNAV, however, one must first assume that the routes are essentially straightline, then redistribute the traffic (alternatively the allocation of flights to RNAV routes may be left to the user).

A final consideration must be addressed: peak day or peak hour operations do not necessarily grow in the same manner as do total yearly operations. If a particular airport is currently operating at or near capacity during its peaks, it is unrealistic to forecast a growth in its peak hour operations which would push it beyond capacity. On the other hand, the duration of peak periods or the number of days that an airport operates at or near peak level may increase. Therefore, annual growth rates must be modified before being applied directly to peak or busy-hour data.

5.1 Terminal Data Set - Type 1

5.1.1 Description

This data set will consist of a peak instantaneous shapshot including all airborne aircraft. Each record will include for each airborne aircraft the following information:

1. Position (x,y) (for instance, latitude and longitude)
2. User category (AC, GA, MI)
3. Flight type (IFR, VFR)
4. Whether flight is local or itinerant
5. Aircraft type category
6. Avionics carried
7. Altitude
8. Speed
9. Heading

In addition, the fraction of all aircraft executing such maneuvers as turns, climbs, and descents will be included, as will the fraction engaged in various communication and navigation activities. Snapshots with these data should be provided for 3 to 5 Large Hub Terminal areas.

5.1.2 Sources

Since this data set consists of snapshot data, data on both VFR and IFR flights and data on avionic equipment usage, three major areas in which existing sources are deficient, a special collection effort will have to be mounted. Two alternatives are described below.

Since the data set is very similar to the data obtained from the LAX Basin Model snapshots, a modified version of the procedures used to generate those snapshots may be suitable. Experience gained in the Long Beach survey will also be used as a guide for the collection procedure. Observers stationed at the airport (at runways, parking aprons, and gates) should record tail numbers and times for all departures and arrivals during a 3-hour period. Other observers should question a sample of pilots on the apron area to obtain information about VFR flight patterns and other relevant matters. IFR flight strip data can be coordinated with the VFR data to obtain input to the Digital Simulation Facility (DSF) at NAFEC or other simulation. (The DSF takes as input a list of flights ordered by departure time and the route flown by each flight together with other information (aircraft speed, for instance) and produces instantaneous flight track data at preset short time intervals. The number of routes which may be provided is limited and each route must contain change points for altitude and heading.) On-board avionics may be obtained from the Aircraft Registration Data using the aircraft tail number, and avionics usage may be assessed from the sampled questionnaire respondents. A special study of communication activity rates may be required.

Several problems arise in conjunction with the above simulation process. The limited number of available routes are used again and again, and the simulated airspace is not utilized as uniformly as in the real world. This tends to obscure anomalies and real situations which occur infrequently. Thus, for studies focussing on infrequent events rather than the typical situation, the data are too averaged to permit meaningful distinctions. In addition, the simulation procedures do not take into account required mid-air separation criteria, so that unrealistic densities occur. Some hand manipulation of 10 to 20% of the data points was required in the LAX basin study to alleviate this condition. However, such manipulation may destroy precisely those situations of interest to some studies (e.g., CAS).

A second method of obtaining current snapshot data would utilize a pilot questionnaire to elicit the required data. A preliminary educational or promotional program would be aimed at the aviation community in general and the GA segment in particular. Questionnaires then would be distributed to all registered pilots, to be filled in at a fixed instant or within a given 30-second interval in time, e.g., "1500 GMT adjusted to local time zone, Saturday, October 13, 1973." The information to be entered could include aircraft type, flight origin and time of origin, destination if known, and for the instant of recording, altitude, position, speed, bearing, attitude and maneuvering if other than straight and level flight. This much information can be accommodated on a short, easy-to-use form without unduly inconveniencing the pilot.

The difficulties and uncertainties of this procedure are, of course, substantial. First, there are analytical problems: temporal variations -- seasonal, day of week, and hourly, and their interaction with regional factors. These will determine the number of surveys to be made. Administrative and feasibility considerations are more serious. Pilot response to non-obligatory questionnaires could be poor. A larger problem is that the variability in pilot cooperation is probably not all random, but rather inversely related to the value of the desired information. Air carrier pilots will likely exhibit the highest response rate and the most reliable responses, while recreational pilots in small aircraft flying VFR, at whom the survey is really aimed and for whose data there is no reliable, independent check, may be the most recalcitrant. The bias arising from total non-response will be compounded by those who avoid flying at the predetermined time of the survey so that they can evade the request to file a questionnaire "with a clear conscience."

Despite the disadvantages, the survey technique has the great advantage, if response can be encouraged, of obtaining directly many of the data which must otherwise be estimated roughly in a simulation procedure, and it should result in better estimates of real world instantaneous separations, altitudes, and avionics usage rates, none of which are presently known.

5.1.3 Forecasting Considerations

A method of "time compression" similar to that used in the 1982 LAX Basin Study [7] can be used for forecasting. Let t_1 be the departure time for a given flight in the current sample, and suppose that the growth rate for this flight category at this airport is g. Then the departure time for a similar flight in the future sample would be $t_o + (t_1 - t_o)/g$ where t_o is the start of the sample time interval. To insure that the future sample time period is the same length as the present, the flight is replicated by dividing the whole interval (say of length L) into g sections and having the flight depart not only at $t_o + (t_1 - t_o)/g$, but also at $t_o + (t_1 - t_o)/g + n \cdot (L/g)$ for n = 1, 2, ..., as long as the departure time is within the present time period. An example is shown below to explain the procedure more fully.

Example:

Assume g = 2.3

t_1 = 1.5 hours

t_o = 0

L = 3

At present we have a departure 1.5 hours after start:

```
|--------|----x----|--------|
0        1         2        3
```

(where the x represents a departure).

For the future we have:

```
|------x-|------x--|--------|
0   .65  1  1.95   2        3
```

since $t_o + (t_1 - t_o)/g = .65$ and $t_o + (t_1 - t_o)/g + 1 \cdot (L/g) = 1.95$ for L/g = 1.3.

(Note: For n = 2, the next departure would be at 3.25, outside the time interval.)

Separate growth rates were provided to the LAX Basin study for each departure airport, category of flight rules, user category and aircraft type category.

Several problems arose in using this procedure for the LAX Basin model study. No changes from year to year in altitudes, speeds, or avionics usage were assumed. (Such changes can of course be exogenously imposed if they can be accurately forecast.) Furthermore, the 1972 routes were also used for 1982; with the route restrictions from using the DSF, this increases bunching of aircraft. A final and even more important problem occurred when average growth rates were used in the LAX basin time compression while the sample time period chosen had heavy traffic. This resulted in departures at some airports violating separation criteria. One could envision using a separate airport simulation to modify departure times to insure a reasonable separation. However, the problem of bunching on aircraft routes is not as easily solved, and a further study of this problem is necessary to determine which technqiues are applicable to the route problem.

Whereas the first method described in 5.1.2 above for collecting a current base for this data set is similar to the LAX Basin effort, and may be amenable to time compression, it is not at all clear that the technique could be applied to the second method, where data are recorded at only one point in time. The compression technique generates data at many different time points and no data have been collected for the other flights which should be included at those points. It might be possible to replicate each flight at different points along its route as determined by a time compression technique, but this would entail collecting route information initially. A further investigation of forecasting techniques for use with an instantaneous airborne sample should be pursued.

5.1.4 Potential Users

1. Frequency Spectrum Analysis

This data set will provide traffic data for analyzing how soon and where the shortage of frequency bands available for ATC voice communication will become critical. Frequency spectrum analysis will require peak traffic levels. Therefore, although it is necessary to insure that any allocation would satisfy users throughout the country, it is sufficient to focus on activity in those areas having the densest traffic, the large hub areas. Although the desire was expressed for including all traffic in an ARTCC, a hub area of 120 miles in diameter would suffice at least for preliminary analysis, since it would approximate the size of an ARTCC sector. A snapshot would be the most useful form of presentation since it would give relative positions of the aircraft in the hub area. Communication and navigation activity rates could then be used in conjunction with maneuvering rates to determine which aircraft are utilizing the frequency spectrum at any one instant and how they might interfere with one another. Changes in equipment requirements could also be modeled. Thus a snapshot of all traffic activity in several large hub areas would satisfy, to a great extent, the requirements for frequency spectrum analysis.

2. Studies for Which Accurate Representation of General Aviation Traffic is Needed

Several studies which are concerned with the consequences of expanding some equipment usage to include all traffic or at least more of the GA traffic, have a self-evident need for GA data. Most such studies need the relative positions of aircraft at a peak instant in time (although some may also require routes flown). Traffic in a large hub area, including GA traffic from satellite non-tower airports, will represent a worst-case situation upon which to test new requirements for GA aircraft. Such data items as aircraft type, altitude, and whether a flight is local or itinerant would be required, since GA flights undoubtedly differ more in profile than do other categories of traffic with respect to these variables.

A primary factor in the acceptance of the LAX Basin Study was its detailed treatment of GA traffic which had been lacking in previous work. Any further traffic data sets offered for general use throughout the Agency must also contain realistic data on GA traffic.

3. Analysis of the Synchronous Garble Problem

The LAX Basin snapshots were used to perform this type of analysis under the assumption that all aircraft were using transponders. The primary data required were three-dimensional positions, used to determine which other aircraft would interfere with any particular aircraft. The analysis showed that the density of traffic in the LAX basin in 1972 was so great that most beacon replies would be garbled if all aircraft were using transponders. This problem raises the question as to whether it is feasible or desirable to require that all flights, including VFR flights, use transponders. At the present time, an estimated 60,000 GA aircraft are transponder-equipped, and this number is increasing.

4. Analysis of Communications Requirements for the Upgraded Third Generation (UTG) Equipment

A large part of the total communication activity is determined by the number of potential conflicts and overtakes as well as the fraction of traffic maneuvering, hence it is necessary to have relative positions of aircraft. The ratio of IFR to VFR traffic is also desired.

Two items are not included in the Type 1 Terminal Data Set, namely (1) diurnal variation to describe the duration of peak and near peak conditions and (2) ground operations. Depending on the method used to obtain this data set, some data on duration of peaks may be available as a by-product of the collection process. In addition, analysis may be useful to quantify the relationship between duration of peaks and communication requirements. The general pattern of ground operations is a consequence of the traffic level and the physical facilities available; this relationship should permit simulation of ground operations, or perhaps a direct representation of the dependence of communication activity upon traffic level and physical facilities can be developed.

The analysis envisioned here emphasizes the general relationship between the communications required and the traffic levels and patterns expected, rather than direct information about the communication activity at any specific airport. Data on specific areas which are candidates for UTG equipment must be collected separately. (It has been assumed from the outset that data commonalities would be stressed, and that analyses which depend greatly on differences in data from different locations could not be fully satisfied by this work.)

5. Analysis of TACAN/DME Saturation

A primary requirement for accomplishing the analysis of how soon the DME portion of a VORTAC is saturated is information on which aircraft have and are using DME equipment, both today and in the future. This information should be collected and included in a current data set. In the event that forecasts may not be available, several different levels of DME usage could be examined to assess the sensitivity of saturation.

Some analysts expressed a desire for data covering quite large geographical areas. However, it is felt that large hub areas should suffice since saturation levels are desired, and only traffic within a comparatively small radius (say 40 or 50 miles) of a navaid would interrogate its DME equipment. Terminal Data Set - Type 1 should provide the essential information required for study of DME saturation, namely the relative positions of aircraft interrogating the DME at any one time.

5.2 Terminal Data Set - Type 2

5.2.1 Description

This data set will contain data for five to ten terminals where traffic (in terms of volume of operations, aircraft type mix, user category mix, local/itinerant ratio, and any other relevant factors) and configuration (in terms of facilities, runways, taxiways, weather, and geographical peculiarities) are representative of the spectrum of those factors found among large and medium-sized terminals. The data set for each airport will contain peak hour arrival and departure rates for all types of air traffic. The fractions of arrivals and departures using each runway will be specified; for each runway, the fractions of traffic which are IFR and VFR, the fraction in each user category (AC, GA, and MI), and the distribution of runway usage by aircraft type category will be provided. In addition, the data will include the fraction of each aircraft type carrying various kinds of avionics equipment, and the average approach, lift-off, and the runway exit speeds.

5.2.2 Sources

Most of these data are already available at the three large New York area airports (EWR, LGA, and JFK) from the CATER data, which includes for each operation: identification, time, type of operation (landing or takeoff), user category, category of flight rules, aircraft type, and runway used. This type of data is potentially available at any terminal at which flight strips are prepared for VFR flights as well as IFR flights. The assigned runway must also be identified on the flight strip. The data could certainly be obtained at any airport with a control tower by stationing extra people in the tower to record the information for each flight.

Data concerning aircraft operating characteristics (such as average landing, taxiing, and lift-off speeds and avionics carried) are available from other FAA sources. Thus this data set is potentially available with a minimum of additional work.

5.2.3 Forecasting

Forecasts now published by the FAA contain most of the types of data required for this data set, except that busy hour operations are predicted for hub areas rather than specific terminals. If a method can be found to modify hub forecasts or to obtain terminal forecasts independently, the basic traffic forecasts will become available. However, it will still be necessary to obtain information on runway utilization. It may be possible to estimate runway usage by assuming that it depends on aircraft type and that the present fraction of each type will be assigned to the same runway in the future. Thus, given the fractions of each aircraft type using a given runway as calculated from 1972 data, the mix of aircraft types, and total operations as already forecast by the FAA, one can estimate the number of aircraft operations on each runway in 1982. If this estimate should exceed the runway capacity, some diversion of aircraft to alternate runways may be necessary and decision rules will have to be adopted at this point.

5.2.4 Potential Users

It is assumed that Terminal Data Set - Type 2 will be input to a user-designed simulation or analytical model for each of the analyses described below. For example, the data set will provide arrival rates for each runway, but an MLS study would have to simulate any desired curved approaches. As a second example, the data set provides arrival and departure rates by aircraft type category for today's conventional aircraft types, but not projections for STOL type aircraft. Those analyzing STOL operations would have the responsibility for such projections.

1. Operational Analysis of a Micro-Wave Landing System (MLS)

As indicated above, it is assumed that simulation and analytical models will be used to study MLS systems in an operational environment and that Terminal Data Set - Type 2 will provide the necessary inputs. The primary data requirement is the number of each type of aircraft desiring to land on each runway in a given time period. Discrimination among aircraft types must be maintained because the MLS requires new equipment in the cockpit, and the fraction of aircraft possessing that equipment may depend on aircraft type. (More expensive aircraft can be expected to carry more equipment.) Peak conditions are the most relevant to test since it is for them that the expeditious flow of landing traffic is most critical. The availability of data for different terminals with different traffic characteristics may also allow studies of trade-off between the benefits of an MLS system and the cost of its installation and operation.

2. Analysis of Airport Surface Control Ground Guidance Systems

Terminal Data Set - Type 2 provides the traffic input data required to simulate systems for guiding aircraft through complex runway and taxiway systems, the primary need being information on the number of departures and arrivals for each runway in a given time period. The main tool for this analysis will be a simulation of the runway, taxiway, apron, and gate areas of the airport surface. Times to taxi along various parts of the system will not be provided in Terminal Data Set - Type 2, but taxiing speeds will. The traffic data will also lack information on the actual taxiway system and gate facilities at any airport; however, this information is available from other sources.

3. Operational Analysis of STOL Systems

Terminal Data Set - Type 2 will provide input traffic data for a simulation of the interactions of STOL and conventional traffic. The major required data items include departures and arrivals on each runway by aircraft type. User category may be of value in selecting the traffic replaced by STOL aircraft. Non-traffic data on airport configurations and operating characteristics for conventional and STOL aircraft are also required.

It is assumed that a user-designed simulation will be the primary tool for analyzing the operation of STOL aircraft in an environment including conventional aircraft. STOL analysts will have to specify the market share allotted to STOL aircraft and to indicate changes in the shares of other aircraft types. The data required to make such projections can be obtained from a study of the economic viability of the STOL concept in various markets, together with projections of demand (in terms of the desired number of trips) between pairs of cities suitable for STOL operations.

4. Analysis of the Wake Turbulence Problem

Studies of the wake turbulence problem, its magnitude and the impact of increased separation or other corrective procedures will require traffic data, primarily aircraft type and runway utilization, as available from this data set.

More than likely, simulation will be a study tool, but analytical models of the vortices created and their dissipation may also be required. (Again, these models must be furnished by the user of the traffic data.) In addition to traffic data, data on runway configuration (in particular, the runway layout, including length, intersection points, and relative positions) will have to be furnished. These data are not part of the traffic data set, but are available from other FAA sources.

5. Analysis of Pollution Problems

The most critical data for analyzing the impact of air traffic on the noise and air pollution of our cities are the levels of traffic landing on and taking off from each runway and the distribution of runway usage by aircraft type. Peak traffic levels, which contribute most to air pollution, are of greatest interest. However, peak air traffic may not coincide with peak air pollution, for other factors (such as non-aviation pollution sources and atmospheric conditions) are significant.

The primary analytical tools are expected to be simulation or mathematical modeling. Data such as emission rates or noise levels as a function of aircraft type will be required, and departure/approach routes will have to be provided by those analyzing the problem. The population distribution in the airport vicinity may also be required. In order to assess the impact of aircraft-caused air pollution, pollution levels from other sources must also be known. In addition, it may be desirable to have data on the diurnal distribution of traffic, since the length of peak and near-peak conditions are relevant to pollution studies.

6. Studies Concerning the Capacity of the Air System

Simulation and, possibly, mathematical models are the major tools available for studying terminal capacity. The primary data requirement is the distribution of landings and takeoffs by runway and the runway usage by aircraft type (since different aircraft have different flight characteristics, such as speed, which affect runway capacity). Other necessary data include the mix of IFR/VFR traffic since different separation rules apply. The duration of peak and near-peak conditions can affect delays, so it is also desirable to have the diurnal variation of traffic level.

7. Studies Which Require Accurate Representation of GA Traffic

The scarcity of data on VFR aircraft operations has made it difficult to assess the impact on the ATC system of many proposed changes in FAA rules and procedures. Better data on VFR activities are expected to be helpful for performing a number of analyses.

The primary data required are levels of terminal operations by user category (to ascertain the fraction which is GA), by category of flight rules and by aircraft type. Some of the problems described above may require only those data for their analysis, but others, particularly the evaluation of various rules changes, may require simulation or mathematical models in addition to the traffic data. Since so little is now recorded about actual patterns of GA traffic, any increase in knowledge about this segment of the flying population enhances the FAA's ability in planning to accommodate GA traffic in terminal areas.

5.3 En Route Data Set - Type 1

5.3.1 Description

This data set will include for each departure in CONUS:

1. flight or aircraft identification
2. origin airport
3. destination airport
4. route flown (airways or fixes)
5. departure time (GMT)
6. arrival time (GMT)
7. category of flight rules (IFR/VFR)
8. user category (AC, GA, or MI)

9. aircraft type category
10. assigned altitude
11. speed (preferably ground speed)
12. avionics carried.

Users have expressed the desire to have these data for all aircraft for the period of a day, but since many GA flights in small aircraft never use the ATC system, it would be difficult (if not impossible) to obtain these data on all flights. However, the users named below may be able to perform their analyses using IFR flights plus those VFR flights for which flight plans are filed. As with the Terminal Data Sets, models specific to particular studies may be required to exploit and supplement the information provided by the traffic data effort.

5.3.2 Sources

The data for this set are essentially available from the FAA IFR peak day sample augmented by VFR traffic with filed flight plans. However, the peak day sample now consists of data based on the individual peaks of the various reporting ATC facilities; it would be preferable to obtain these data for the same reporting period from each facility. This requires selection of a common period which is most representative of a system-wide peak.

Two items (route flown and arrival time) are not now collected. Route flown might be approximated from flight plan information, but this would require much hand-matching of data. Route flown would also be directly available from the NAS computer system, another source of the IFR data,since the route is part of a stored flight plan record.

Processing computer tape output from all 20 NAS centers would be a large job, but the possible benefits might warrant the effort. In addition, once programs have been written to accomplish this task, they could be repeated on future outputs. Arrival time is not currently included in the computer system, nor will it be in the foreseeable future. If and when metering and spacing programs are implemented at ARTS III terminals, a "drop track" message will be relayed from ARTS to NAS when an aircraft is about 2 miles from touchdown. Such a message could be used as a surrogate for arrival when it is implemented, but even then it will be available only at ARTS III terminals (and possibly not even at all of these). If route information is available through the NAS computer output, it should also be possible to approximate arrival time from the last reported time and fix. Though not taking into account the effect of terminal delay, this would be better than approximations based on average speed for the whole route.

5.3.3 Forecasting

As for Terminal Data Set - Type 1, the method of forecasting should be some form of time compression, hence practically all comments on that data set apply. Some additional comments regarding the growth rates used in the time compression method of forecasting follow.

Even though this data set applies to en route centers, the growth rates at terminal areas are of primary concern: the method of forecasting must utilize the growth rates for the origin-destination pair associated with each recorded flight record on the peak day tapes. Before applying growth rates to the peak day records, an attempt should be made to combine the growth rates at the origin and destination of each pair of airports into a composite rate for the pair.

Procedures for combining growth rates are already available in the transportation literature. A crude example, labeled the proportional trip distribution model by Potts and Oliver [15], yields

$$d_{ij} = \frac{g_i \, g_j (\sum_j x_{ij})(\sum_i x_{ij})}{\sum_i \sum_j g_i \, x_{ij}}$$

where d_{ij} is the forecast demand between airports i and j,

g_i and g_j the predicted growth rates for airports i and j respectively,

and x_{ij} is the current demand between i and j.

Changes in route structures will not be reflected in such a procedure, nor will changes in altitudes flown and departure time distributions. Such changes must be forecast separately and imposed exogenously.

5.3.4 Potential Users

1. Analysis of the RNAV Concept

Studies comparing usage of the RNAV system to that of the present system will require simulation of both systems with the traffic data set described above as an input. It will be necessary to designate which flights will use RNAV routes rather than the routes given in the data set. (This breakdown of traffic into RNAV and non-RNAV is external to the traffic data effort, as will be the assignment of RNAV traffic to RNAV-routes.) The primary traffic data required by this study will be the origin, destination and (conventional) route flown. Aircraft type and user category may also be relevant in choosing whether a conventional or RNAV route will be used, since the fraction of aircraft having RNAV equipment may vary with type and user category. Thus, the En Route Data Set - Type 1 will contain the basic traffic data required for a study of the RNAV system.

2. Analysis of IFF/ECM Interference

The traffic data available in En Route Data Set Type 1 can be used to study how often jammed IFF response might occur, to investigate methods for detecting deliberate jamming, and to study means of identifying intruders in spite of the various interferences.

The main geographical areas of interest are along the boundaries of North America. Data are needed for all traffic, including VFR, since any intruder would appear on radar similar to a VFR flight. However, due to the IFF problem, VFR flights in boundary areas must file with the appropriate authorities, hence pertinent data should be available. Route flown, or at least the intended route, is available from this data set, but actual track (which may deviate from the route filed) will not be included. Perhaps some statistical simulation model can be used to generate realistic deviations from filed routes.

The data set, as described above, covers only CONUS, not all of North America. It is hoped that some phases of the problem can be studied by using a sample of areas in CONUS as representative of those required for the study. In any case, since this analysis is unique in its requirement for detailed data over such a large geographical area, its accommodation is impractical within the general-usage thrust of the traffic data effort described here; perhaps the military would wish to undertake the requisite data collection and study. Some areas of interest, such as the Gulf Coast, would be included in the data set, and an analysis could be performed on these to yield at least partial results.

3. Analysis of the Capacity of the En Route ATC System

As with many other prospective studies, simulation is expected to be the main tool for the analysis of en route capacity. The En Route Data Set will provide realistic peak traffic levels, but additional data will be required to establish a relationship between controller communication activity and aircraft maneuvers and to relate controller workload to traffic levels and characteristics of a particular sector. Sector boundaries will also be required. Measurement of the airways' absolute capacity does not require traffic data, but if delay is to be taken into account, various levels of traffic may be required and would be available from this data set.

5.4 En Route Data Set - Type 2

5.4.1 Description

The data sets described above apply to individual aircraft either directly or statistically generated. However, not all analyses require such detailed data. The data set described in this section consists of peak instantaneous airborne aircraft counts (IAC) for en route ATC sectors. A number of analysts have expressed the need for peak IAC for each sector in CONUS. It is hoped that some classification of sectors by such items as number of airways, number of airway intersections, number of towers, or aircraft handled, etc., may be possible, so that instantaneous counts need be obtained only for representative classes, rather than for all sectors. Although a desire was expressed for all traffic, the analyses described below all relate to the ATC system, hence IFR traffic would be sufficient. Background counts of the number of VFR aircraft, or at least the number of "blips" on the radar screen coincident with the peak IFR count, are also desired. In addition to the IAC, the distributions of various sorts of communications activity as functions of traffic level and sector characteristics are required.

5.4.2 Sources

The main requirement, that for peak instantaneous IFR traffic counts for en route sectors, can be met from the NAS computer diagnostic tapes. (See the Appendix for a more detailed description of NAS computer operation.) The NAS computers must keep track of the number of active flight records for each sector and the status of each. Thus a special post-processing program would be written (or may already be available) to process the NAS output off-line and obtain peak instantaneous counts.

A measure of the number of false radar returns may be obtained either by examining radar scope pictures or from diagnostic output of the NAS tracking system. (The latter is in the preliminary stages of implementation; more complete and detailed information on its operation is required to evaluate this source more fully.) A separate analysis of communication activity as a function of traffic level and sector characteristics may be required, or, at least an examination of current communication studies which might shed light on the relationships between traffic and communication activity levels.

5.4.3 Forecasting

It should not be too difficult to obtain the present day data for this data set, assuming that sampling by class is possible. Forecasting these items, may, however, prove to be much more difficult. One approach might be to develop a functional relationship among the sector characteristics defining the sectors in the data set, the expected traffic levels which are currently being forecast for some of those characteristics, and the current instantaneous airborne counts. Such a functional relationship would permit forecasts of future IAC's. Using cross-sectional data as a basis for obtaining time-dependent estimates must be done with great care but may be the only technique available here.

Insofar as predictions of background noise level are concerned, the only comment is that this will probably involve analysis of radar capabilities.

5.4.4 Potential Users

1. Estimating the Required Size of NAS Stage A Computers

Computer size requirements being greatly affected by the amount of data to be processed, traffic levels must be projected over the major portion of the equipment's life. Only IFR traffic would be stored in the computer's data bank, but VFR traffic causes primary radar returns as a background "noise" level which affects the amount of processing required to discriminate IFR returns from the noise. Some indication of this background level of non-IFR returns is therefore needed. Other required information, not directly related to traffic, includes number of sectors and characteristics of the airway structure in each ARTCC, and should be available from sources other than the traffic data sets. It is expected that predictions of the IAC will be input to analytical models or equations which calculate parameters relevant to computer size. Again, the design of such models and equations is not part of the effort described here.

2. Assigning Voice Communication Frequencies to En Route Sectors

The main traffic data required to analyze frequency assignment to sectors are those sectors' peak IAC's. Since voice communication must be available independent of the environment, a worst case analysis using peak data is desirable. Actual position within a sector can affect the degree to which signals from different aircraft in the same or different sectors can interfere with one another, but in the absence of actual position data the worst case assumption can be applied. Along with the output of the traffic data effort, sector boundary specifications and a model of frequency interactions are also required for this analysis.

3. Analyzing the Communications Requirements for the Upgraded Third Generation (UTG) System

Assessing the communications requirements generated by future ATC systems will necessitate having peak traffic counts, as well as the distribution of communications activity. The traffic data effort will include communications activity rates for the current system configuration, but it will not relate these rates to the UTG system specifications.

5.5 Oceanic Data Set

5.5.1 Description

This data set will be made up of all North Atlantic traffic including air carrier, foreign flags, supplementals, military, and non-air carrier as well as traffic which neither originates nor terminates in the U.S. The data will consist of the number of flights per day between all pairs of cities. For each origin/destination pair, the fraction of traffic using each oceanic route, the fraction of flights of each aircraft type, the daily (actual) departure time distribution, and the distribution of flight duration will be provided. In addition, the avionics carried by each aircraft type category will be specified.

A simplified version might allot all flights for a given city pair to a single route; provide the fraction of flights of each aircraft type for only three categories: jet, large (4-engine or more) piston, small piston; and develop an assumed flight duration. This might be enhanced by developing a set of departure time distributions which depend not on city pair directly, but rather on the flight duration, with an offset to take into account the origin time zone.

Although this data set would contain only North Atlantic traffic, there is also a requirement for other oceanic traffic, particularly for the Pacific. If the cost were reasonable, it would be of great value to obtain these additional data, particularly for assessing the effectiveness of world-wide oceanic navigation systems.

5.5.2 Sources

The Oceanic Data Set will necessitate a special collection effort since data are currently lacking for non-air carrier trans-oceanic flights. If all international departure points, or alternatively, all coastal sectors, kept data for each oceanic flight on one day, the data set could be constructed. Such an effort would, of course, have to be coordinated by an international group such as ICAO, in order to obtain data on all oceanic flights, including those which neither land in nor depart from the U.S. It would be desirable to record departure and arrival times to construct distributions by pairs of cities. If these times cannot be recorded, a special study of departure time distributions for city pairs at various separations might be conducted. Such a construction implies that departure time distribution is primarily a function of the travel time between two cities and of the origin time zone.

The break in surveillance of trans-oceanic flights precludes obtaining the actual track flown. A special study [13] to estimate mean deviation from nominal track for the North Atlantic has been accomplished with a radar-equipped ship in mid-ocean under one of the heavily traveled routes to record aircraft position.

5.5.3 Forecasting

The required data are similar to those required for En Route Data Set Type 2, although not as detailed. A similar forecasting procedure might be applied if international flight growth rates can be estimated. As traffic increases, a study of the growth rates for all countries which affect trans-oceanic flights would certainly be desirable. Changes in departure time distributions may be predicted as a function of changes in aircraft mix which reduce time between cities and expansions of traffic levels which tend to flatten out peaks.

5.5.4 Potential Users

1. Study of Oceanic Navigation Systems, Especially OMEGA

In order to assess the benefits of OMEGA with regard to increased safety or a reduction in the present trans-oceanic separation standards, trans-oceanic air traffic data are needed. A desire was expressed for data on actual tracks flown in order to evaluate the deviations from planned tracks under use of current navigation systems. However, the lack of surveillance of trans-oceanic flights makes such data unavailable. The Oceanic Data Set, though lacking track deviation data, would provide information on actual traffic levels handled by the current system; this could be combined in a special study (not within the province of the traffic models effort) of track deviations and their propagation when inertial navigation systems are used. Future traffic levels could be used to assess the demands on a new navigation system. Of course, those demands could include overland air transportation and ships at sea as well as trans-oceanic air traffic.

2. Sizing Oceanic Sectors for NAS Stage A

The Oceanic Data Set would provide the necessary data for analysis of East Coast sector sizing. Some modeling by the user would be required to pass from the basic numbers provided by the data set to the desired peak instantaneous airborne counts. Pacific sectors would not be included in the data set unless, as mentioned above, the data collection is economically feasible. In the absence of West Coast data, the sizing of Western oceanic sectors would lack a satisfactory empirical basis, hence the data set is not wholly adequate for this application.

3. Reconfiguring the Flight Information Regions (FIR'S)

The Oceanic Data Set would provide a valuable input to an analysis of the reconfiguration of FIR's. These data would enter a user-developed model designed to simulate aircraft movements along specified routes in order to determine such relevant factors as instantaneous airborne counts for each region and the number of boundary crossings. Departure time distribution is critical since the IAC is affected greatly by bunched departures.

4. Assessing Satellite Navigation Power Requirements

The determination of power requirements for a satellite system interrogated by aircraft will depend on the expected number of interrogations which, in turn, requires traffic data of the type described. These data would probably be input to a simulation model which describes the aircraft movements and satellite interrogation rates.

6.0 FINDINGS AND RECOMMENDATIONS

The FAA Models Committee Report [17] recommended that, to decrease duplication of effort and to ensure more consistent analysis of air traffic problems, a centralized data collection, assimilation, and processing effort should be initiated to provide common air traffic data for all FAA analyses. An initial effort designed to test collection and forecasting methods, as well as to stimulate further discussion of Agency needs, was undertaken during the Fall of 1972. This resulted in the LAX Basin Model Study and a subsequent survey aimed primarily at general aviation flights at the Long Beach, California airport.

After preliminary results of the LAX Basin Study were available, and concurrent with the Long Beach Survey, the present study was initiated to investigate the feasibility of identifying common traffic data requirements and format, to consider related data processing techniques (i.e., mathematical models, simulations, forecasting techniques etc.), and to recommend courses of implementation action.

During this study, approximately 24 different FAA analyses requiring traffic data were considered and interviews were conducted with the responsible analysts to determine data requirements. Simultaneously, existing FAA data collection efforts and sources were examined to assess the adequacy of current data availability and to examine those requirements not satisfied. The major data lacks appeared to be concerned with VFR aircraft and with instantaneous airborne positions. Recommendations for obtaining those data are included in this report.

The needs having been identified, common requirements were grouped into five different data sets consisting of the following information:

1. Instantaneous position data from several large terminal areas.
2. Arrival and departure rates from several large, medium, and small terminals.
3. Origin/Destination (O/D) data for all IFR and certain VFR flights for the coterminous United States.
4. Peak IFR counts for ATC en route sectors.
5. Oceanic O/D data for the North Atlantic.

A single data collection effort similar to the LAX Basin study would obtain present-day values for Data Sets 1 and 2 for large terminals, if departure or arrival runway is specified for each flight. Special care is required in collecting VFR data, but preliminary results from the Long Beach survey indicate that, with sufficient manpower familiar with the local air traffic situation, such a collection effort can provide valuable data not now available elsewhere. Additional data collection efforts will be required to obtain Data Set 2 at small and medium airports, but the effort required is significantly less than that for large terminals.

The IFR O/D data required by Data Set 3 is currently available from each FAA facility for a peak day. Therefore a special effort aimed at a single day of the year is feasible, requiring only that reports be filed for that day in addition to the peak day. This puts an additional demand on field personnel that may be avoided by processing NAS and ARTS computer output tapes. The VFR O/D data may be obtained from filed flight plans, but some actual flights may not be recorded by this procedure. The peak sector counts required by En Route Data Set Type 2 should also be available from off-line processing of NAS computer outputs.

Collection of oceanic data for certain tracks between San Francisco/Los Angeles and Hawaii started in December, 1973. North Atlantic O/D data have been collected; additional data collection efforts, coordinated by an international body such as ICAO, are possible.

Further collection efforts and analyses relating navigation and communications activity to traffic levels and ATC system characteristics are required by many of the users interviewed.

Most analyses currently under way or anticipated require traffic data for some future date, usually about 10 years hence. Further investigation of forecasting methods and their applicability to the data forms described above should be undertaken. Preliminary analysis accomplished during this study indicates that a modification of the time compression technique used in the LAX Basin Study may be appropriate for forecasting the forms in Data Sets 1, 3, and 5. The forecast data required by Type 2 may be directly available from present FAA forecasts with only a slight variation representing distribution among runways. Data Set 4 may require an entirely different technique and must be studied further.

Five data sets (two each for the terminal and en route areas and one for oceanic areas) have been identified as candidates which would satisfy a substantial portion of air traffic situation data requirements for analyses of anticipated NAS problems. Suggestions have been made as to sources and means for collecting the specified data, as well as possible methods for projecting these data to future time horizons. The study indicates the feasibility of establishing common data and sources to satisfy the air traffic situation data requirements for the majority of NAS analyses. Furthermore, the practicality of gathering the data and the resources required were addressed at a general level.

Priorities among the different data collection efforts depend upon the priorities of the various user programs. Since this is subject to FAA and DOT policy decisions, our recommendations are governed primarily by our assessment of the criticality of current data gaps, rather than program priorities.

Since the most critical element of the NAS is the terminal area where the interaction of VFR and IFR operations is most visible, it is recommended that initial efforts be directed toward collecting the data specified in Terminal Data Sets Types 1 and 2. The sample terminal areas for this pilot effort should be selected to provide information required by some on-going studies. Additional objectives would be to develop effective data collection and validation procedures and improved methodology for forecasting air traffic information.

A collection effort has been considered in the Chicago area including not only the O'Hare terminal area, but also the Chicago Center. The characteristics of Chicago -- a high percentage of IFR operations and the large number of overflights, as contrasted with Los Angeles or Miami -- make it a desirable area in which to perform such a survey. Care should be taken to obtain the runway data from O'Hare for all departures and arrivals so that the data may be used for both Terminal Data Sets. Other areas might be candidates for future surveys, such as New York with its 3 major airports, Cleveland ARTCC with a large number of overflights, or Denver or Atlanta which have been used for previous studies. The principal criteria should be that characteristics be relatively distinctive and applicable to the analyses being performed.

Considerable emphasis has been placed here on the present lack of information on VFR operations and the need to correct this deficiency. The implementation of a pilot program for the collection of Terminal Data Sets, Types 1 & 2, could provide more information on VFR operations if the selected sample terminal areas contain satellite general aviation airports. However, the patterns and habits of VFR operations conducted in such environments probably differ from those at the smaller non-tower general aviation airports, which are more isolated from the main streams of air traffic. As has been pointed out, the latter VFR operations may represent a substantial portion of total VFR activity which is not included in present FAA traffic counts. It is therefore recommended that a representative sample of small airports be surveyed in several areas of the CONUS using a modified Long Beach technique. The information thus collected would be a significant input for improved general aviation forecasts.

APPENDIX A

POTENTIAL OF THE TRAFFIC DATA IN NAS STAGE A & ARTS III COMPUTERS

The recently installed NAS Stage A and ARTS III Systems change the nation's air traffic control system from a manual operation to a semi-automated one. This is only the first step toward a more complete automation of the ATC System.

There are actually many models and versions of NAS Stage A and ARTS III systems. Basically, however, each system consists of the three following major sub-systems:

- Data Acquisition Subsystem: Digitizes the radar and beacon data and transmits them to the central computer
- Data Processing Subsystem: The central computer complex which controls the peripheral equipment as well as the data processing.
- Display Subsystem: Processes and controls the data for display.

Individual installations of each of the above subsystems differ in both hardware and software aspects. In fact, equipment modification at the various centers and terminals has been a continuous effort, and no one individual, at this stage of implementation, is familiar with all of the detailed changes among the various models and versions of NAS Stage A and ARTS III systems.

The amount of data processed by the en route or terminal computers is immense, containing information for computer command, radar beacon signals, weather maps, flight plans, etc. However, the data of major interest to this effort are those related to air traffic.

The air traffic data available in the en route and terminal computers are especially useful in two respects: (1) the computer data contain real time air traffic information, rather than monthly or yearly average data; and (2) they provide precise track information for each aircraft.

The following sections will briefly outline the data flow (traffic data only) in the NAS Stage A and ARTS III Systems.

NAS Stage A

Figure A.1 shows the data flows in the NAS Stage A System. The NAS Stage A System has the option of transferring the data from the core storage of the Central Computer Complex (an IBM 9020 computer) to the System Analysis Recording (SAR) tape. The resulting SAR tape is processed off-line by programs in the NAS Operational Support System (NOSS), a large utility system consisting of many parts. Those of interest to this effort are the Data Reduction & Analysis (DR&A) programs. The DR&A programs as currently constituted deal not only with traffic information, but also certain monitoring functions.

The functions of the various programs in the DR&A are summarized below:

Station Log Program: Analyzes the messages which have been recorded on the SAR tape file and determines the message type, station, aircraft identification, time, device, etc.

Flight Plan Data Base Analysis Program: Prints information concerning dynamic data pertaining to a given aircraft whenever any external controller's actions are entered into the computer for that aircraft.

Input/Output Message Summary Program: Summarizes all I/O data for all operational positions, sectors, and devices.

Track Data Base Analysis Program: Displays and calculates selected information from the track data base approximately every 5 seconds.

Track Data Base Analysis Summary: Summarizes and provides statistics on the data selected by the Chronological Log Program.

Radar Track History Program: Provides a history of a subset of the total number of tracks in the system. All of the radar data pertaining to a given selected track are listed once every second. Other listed data include time the data were received, plus the track, radar, and computer identifications.

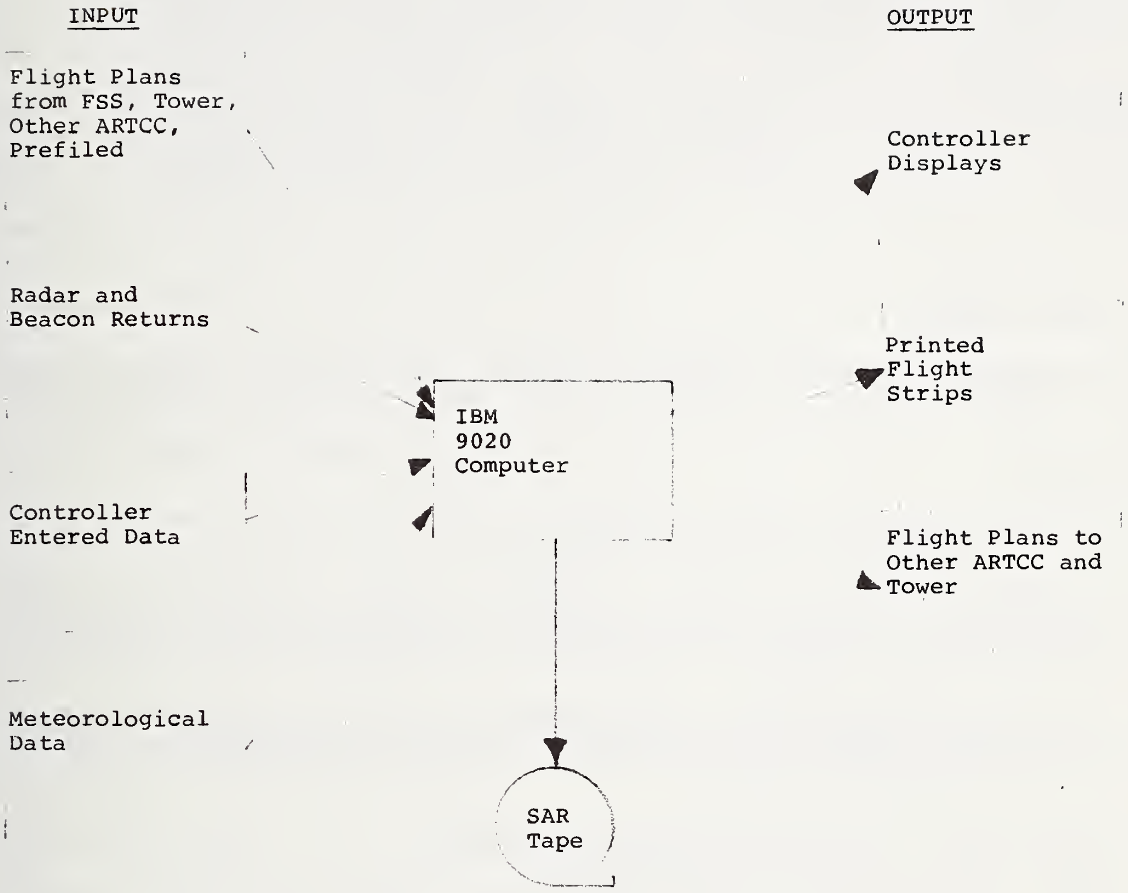

FIGURE A.1: DATA FLOWS IN THE NAS STAGE A SYSTEM

ARTS III

The terminal computer system has parts corresponding to those in the en route system. The data flows in the ARTS III system are similar to those in NAS Stage A. The output tape of the Data Extractor Routine corresponds to the SAR tape in the en route system, and has several options to extract data depending on user needs.

The extraction tape can be processed further off-line by the Data Reduction Program which corresponds to the DR & A programs in the en route system, but is less extensive. The output items and their functions are shown below:

Sector Time: Provides the current time and the types of beacon subsystem.

DAS Reports: Contains types of beacon subsystems, azimuth, ranges, beacon code and beacon mode.

DAS Replies: Contains types of beacon subsystem reply condition, azimuth, beacon code and range.

Tracking Message: Contains current time, aircraft identification, altitude, assigned and reported beacon code, azimuth, range, X and Y coordinates, and velocity.

Keyboard Input: Provides current time, aircraft, identification, altitude and the message.

Auto Functions: Provides aircraft identification, altitude, mode of auto functions (e.g., auto acquire, auto assign code, etc.)

Arrival Flight Plan Message from ARTCC to ARTS III: Consists of current time, ARTCC identification, message number, flight plan, aircraft identification, arrival coordination fix, arrival coordination time at coordination fix, altitude and airport of intended landing.

Departure Flight Plan Message from ARTCC to ARTS III: Consists of current time, ARTCC identification, message number, flight plan, aircraft identification, departure point, assigned beacon code, departure coordination fix, proposed departure coordination time and altitude.

Beacon Identification: Consists of current time, trial track, assigned beacon code, azimuth range, X and Y coordinates, and velocity.

Trial Track: Consists of current time, trial track, assigned beacon code, azimuth, range, X and Y coordinates and velocity.

Discussion

The NAS Stage A and ARTS III Systems will certainly change the availability and composition of traffic data. Currently 20 ARTCC's and 61 of the nation's busiest airport terminals are equipped with either the NAS Stage A or ARTS III Systems. These 61 airports serve about 70% of the total domestically enplaned passengers and 38% of all itinerant operations at FAA-operated airport traffic control towers [6]. By 1980 there will be 200 ARTS III Systems installed nationwide [2]. The NAS Stage A, model 3D system will have both beacon tracking and radar tracking capability [10], and is currently being installed in place of the original version of the en route system. The current ARTS III Systems have only a beacon tracking capability and can thus track only those aircraft equipped with transponders. It is estimated that about 60% of the aircraft in GA fleet are presently equipped with transponders, and this number is expected to increase in the future. However, an add-on primary radar tracking subsystem has been developed for the ARTS III System [5]. Test and evaluation [4] of this subsystem show that the radar-only tracking feature is satisfactory, and that the radar tracking reliability for large aircraft is comparable to that for beacon tracking. All of these improvements tend gradually to narrow down the VFR data gap. However, this gap may never be completely closed because about 80% of airports in this country do not have any kind of FAA control facility and neither primary radar tracking nor beacon tracking is 100% reliable.

Analyzing the NAS Stage A and ARTS III traffic data may be costly and difficult, primarily because of the immense volume of traffic information recorded by the computers. For example, on a typical day at the Cleveland ARTCC, in a 13-hour span (from 1420

Aug. 10, 73 to 0330 Aug. 11, 73), nine reels of SAR tapes were generated.* The average time span covered by each tape was 1 hour and 28 minutes, the exact time span depending on traffic conditions. The situation is similar for the terminal system. The ARTS III can record on one extraction tape (2400 ft., 200 bpi) about 2 hours of traffic** depending upon the traffic condition and the kind of information being recorded. To merge and combine the data tapes recorded at different centers and terminals increases the cost and difficulty by an order of magnitude, particularly since output tapes from different ATC facilities may not be compatible.

The volume of air traffic data generated by the NAS Stage A and ARTS III systems creates a requirement for great care and effort in selecting only those data which are necessary for analytical purposes.

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* Dr. Jan Shannon, ARD 110, FAA, private communication.

**Joseph Kowalewski, NAFEC, private communication.

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GLOSSARY

AC	Air Carrier
a/c	Aircraft
ARTCC	Air Route Traffic Control Center
ARTS III	Automated Radar Terminal System
ATC	Air Traffic Control
ATCAC	Air Traffic Control Advisory Committee
B747	Boeing 747 Aircraft
CAB	Civil Aeronautics Board
CAP	Civil Air Patrol
CAS	Collision Avoidance System
CATER	Collection and Analysis of Terminal Record
CONUS	Continental United States
CSC	Computer Sciences Corporation
CS/T	Combined Station/Tower
DAS	Data Acquisition System
DCA	Washington National Airport
DC10	Douglas 10 Aircraft
DME	Distance Measuring Equipment
DOT	Department of Transportation
DR&A	Data Reduction and Analysis
DSF	Digital Simulation Facility
ECAC	Electromagnetic Compatibility Analysis Center
ECM	Electromagnetic Countermeasure
EWR	Newark Airport
FAA	Federal Aviation Administration
FIR	Flight Information Region
FSS	Flight Service Station
FY	Fiscal Year
GA	General Aviation
GMT	Greenwich Mean Time
IAC	Instantaneous Airborne Count
ICAO	International Civil Aviation Organization
IFF	Identification - Friend or Foe
IFR	Instrument Flight Rules
IFSS	International Flight Service Station
ILS	Instrument Landing System
I/O	Input/output
JFK	John F. Kennedy International Airport
kHz	Kilohertz
LAX	Los Angeles International Airport
LGA	LaGuardia International Airport
L1011	Lockheed Tristar Aircraft
MI	Military
MITRE	the MITRE Corporation
MLS	Microwave Landing System
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NAS Stage A	Enroute Automation Program
NOAA	National Oceanic and Atmospheric Administration
O/D	Origin/Destination
OMEGA	Long range navigation system
ORD	O'Hare International Airport
RNAV	Area Navigation
RSM	Requirements Source Matrix
SAR	System Analysis and Recording
SID	Standard Instrument Departure
SMSA	Standard Metropolitan Statistical Area
STAR	Standard Terminal Arrival Route
STOL	Short Takeoff and Landing
TACAN	Tactical Air Navigation
TCA	Terminal Control Area
uhf	Ultrahigh Frequency
UTG	Upgraded Third Generation
VFR	Visual Flight Rules
vhf	Very High Frequency
vlf	Very Low Frequency
VOR	Very High Frequency Omnirange Station
VORTAC	Co-located VOR and TACAN

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report describes activities undertaken to assess the practicability of establishing a single file or a set of files of standard reference air traffic data samples. These files would serve as a common data base for ongoing and anticipated future forecast and analytical investigations relevant to the accommodation of air traffic in the National Airspace System.

The study entailed surveys of past and present air traffic data collection activities, of existing data files, and of all identifiable users of air traffic data within the FAA, as well as FAA contractors whose work requires air traffic data.

The information resulting from these surveys has been evaluated and aggregated to identify data which will satisfy most of the requirements expressed by the data users. Two data sets are specified for terminal area requirements, two sets for en route requirements, and one set for oceanic requirements. These data sets will satisfy most input requirements for all anticipated analysis efforts. However, depending on the type of study, supplemental information, which is identified in various parts of this report, will be required in some cases.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Air traffic analyses; air traffic data; standard reference air traffic data; users of air traffic data.

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