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AIR TRAFFIC CONTROL IN THE YEAR 2000

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Joseph M. Del Balzo

NOVEMBER 1977

FINAL REPORT

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16. Abstract

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1. INTRODUCTION.

In spite of the title, this paper does not describe ATC in the Year 2000. It starts instead by reviewing the capability of existing technologies and the application of these technologies to several critical air traffic control functions and concludes that sufficient technology is available today which, if intelligently selected and applied, can accommodate commercial aviation and the future growth of general aviation operations. The paper points out that while the role of application of some technologies in a future ATC system are self evident (Remote Maintenance Monitoring, Computer Image Displays in a TRACON, MLS, RNAV, Computer Voice Entry, Computer Voice Recognition for Mass Weather Dissemination, alternate source of energy, etc.) the application and role of other more important technologies (satellites for communication, surveillance and navigation; cockpit display of traffic information, advanced computer technology; color displays, automated terminal services) are critically dependent on the answers to a series of difficult questions on the operational philosophy against which the future ATC system is to be designed and concludes that only after these questions have been answered can the ATC system in the year 2000 be defined. Technology is not the limiting factor; what is needed is an operational philosophy for the future.

2. TECHNOLOGY REVIEW.

a. DATA ENTRY AND DISPLAY TECHNOLOGY.

(1) *Reintroducing the Color Display* - Several years ago, the National Aviation Facilities Experimental Center (NAFEC) conducted an investigation and evaluation of the operational benefits that could be derived by using color as a discrimination element for ATC traffic situation displays. These experiments were severely limited due to available computer capacity, software generation capability, and the ability to identify and pin down a wide range of potential color applications to the ATC traffic control and management functions. Continuing improvements in the state-of-the-art of color displays in terms of resolution, color registration at the edge of the display, capacity, size brightness (although still at a level significantly below that of existing monochromatic CRTs), and speed, coupled with increasing demands on the controller in the pursuit of his day-to-day traffic control and management job, suggest that the time is now right for a reinvestigation of the entire color display question. The agency is initiating a program to identify candidate operational applications of color to the ATC management and control job of the future.

(2) *Voice Data Entry* - The present National Airspace System requires large quantities of data entry, on-line and in real time. In Air Route Traffic Control Centers, radar controllers and nonradar controllers must enter hundreds of flight progress, flight plan amendment, and other messages every work shift. These messages must be entered through the use of keyboards and the "computer readout displays" and encompass thousands of keystrikes by each operator on every tour of duty. Data entry through keyboards can be very rapid and very

accurate but it necessarily distracts the person who does it from other activities. Voice data entry, if it can prove at least as accurate and almost as rapid as key entry, should also prove to be far less distracting to air traffic control operators.

NAFEC has been experimenting with a word recognition device since 1975. The keyboard entry language of the most heavily burdened (in key-entry workload) air traffic control position in the National Airspace System has been analyzed and a spoken equivalent language has been designed. The recognition accuracy of the word recognition device has been tested exhaustively for each of several of the "parts of speech" or subvocabularies in this spoken language--namely the list of message types ("amend," "handoff," etc.), the digits zero through nine, and an inclusive list of geographic fixes drawn from an actual ARTCC sector. After much testing with different speakers, software was designed and assembled to compose complete entry messages by means of the spoken language. An optimum error-reduction method was developed and preliminary data on full message entry indicates that voice messages can be input at the equivalent rate of three or four keystrikes per second at an average accuracy of 99.5 percent. Comparative data for keyboard input of the same messages is now being obtained. Following these comparative tests, this activity is expected to take two directions. One will be the preparation of a field evaluation model of the device. This will be a smaller, more compact unit (about the size of a "carry-on" suitcase) completely programmed and interfaced to connect in parallel with the NAS keyboard at the nonradar controller positions in the enroute centers. It is intended to bring this unit to several ARTCC's for use by controllers during light traffic periods. This plan is intended to assess user acceptability and to detect needs for improvement or modification. The device will then be interfaced with the Air Traffic Control Simulation Facility at NAFEC. Here it will be tested in use during the control of simulated traffic under heavy traffic conditions. The purpose of this effort is to assess the effects on user acceptance as well as accuracy of input of workload-induced operator stress.

Follow-on activities which are currently envisioned are of two types. One is the adaptation of word recognition techniques to other ATC data entry applications, particularly in control tower operations. The other direction, which depends largely on the development elsewhere of the state-of-the-art, is the evaluation of *speech understanding* techniques as a means of extracting relevant system entry data from the more detailed and continuous speech characteristic of ground-to-air voice communications. The technology of voice data entry will have come of age to support the ATC system in the year 2000. Can it be used?

(3) *Controller Displays of the Future* - The introduction into the tower cab of new systems (WVAS, wind shear, TIPS, ASTC, etc.) and computer data processing will significantly enhance controller productivity and effectiveness; however, the on-going integration of advanced functions magnifies the overall problem of tower information display. Historically, cab design has been influenced by packaging considerations associated with various information generating or information conveying devices such as NAVAID monitors, communication panels, data entry keypacks, weather instrumentation, lighting control panels, and radar displays. As new functions are added to this inventory, tower cab

consoles must be expanded to accommodate new devices, with a resultant increase in very high-cost floor space. In addition, cabling between these devices and external sensors or interfaces, on the lower levels of the tower building, becomes more complex and expensive to install and maintain. Of perhaps even greater significance is the problem of controller overload with too many discrete and sometimes confusing pieces of information which cannot be instantly comprehended. The integration of new functions (and the inevitable future developments), such as the presentation of wind data, is digital readouts; new type status panels for NAVAIDS monitoring; elimination of status boards and an instant call-up of approach plates; display information of the Visual Confirmation of Voice Takeoff Clearance System which is now under development, etc., cannot be approached on piece meal basis.

Again, technology comes to the rescue! The use of computer generated imagery/symbology as a replacement for discrete analogue type displays has promising possibilities. This imagery, addressed by touch sensitive circuitry, incorporated within the viewing screen (or by keypack or voice entry) will allow for user call-up of information on demand, or through priority forcing. In addition to the multi-use of display space, computer generated imagery offers significant cost savings.

b. COCKPIT DISPLAY OF TRAFFIC INFORMATION.

For at least 30 years (the Teleran system which was based on TV transmission of ground radar information and map overlays to aircraft was developed by RCA in the late 1940's) there has been controversy about the possibility of display of air traffic data to the pilot. Until recently, the state of technology made cockpit display of traffic information too complex and costly to warrant serious consideration. With recent improvements in computers, CRT displays, and the projected availability of beacon collision avoidance systems and DABS data link, the means to provide traffic information in the cockpit appears now to be economically and technically feasible.

The possible methods of displaying traffic information include, but are not limited to:

- Incorporation on RNAV CRT map displays.
- Integration with digital weather radar displays.
- Integration with EHSI, EADI, or other multifunction cockpit displays.
- Presentation on dedicated displays such as proposed for ATARS (IPC) or BCAS.

Typical cockpit displays have been suggested for presenting traffic data in both current and future generation cockpits. All forms of traffic display are envisioned to be used with suitable alarms to call attention to the pilot when a potential conflict is developing. It is also envisioned that conflict resolution advisories such as provided by BCAS or ATARS (IPC) could be used with traffic display.

Various ATC dependent and independent sources for deriving and transmitting traffic data have been proposed including:

- NAS/ARTS or DABS data base via the DABS data link [in conjunction with ATARS (IPC)].

- NAS/ARTS or DABS data via the proposed DABS broadcast mode.

- NAS/ARTS or DABS via UHF or VHF broadcast data link.

- Passive BCAS/DABS CAS.

- Air-to-air cooperative data links such as JTIDS.

Again, technology is not the limiting factor. However, important questions remain about how a pilot might use this information effectively in an operational environment. Since the pilot is now an active participant in the control process, and no doubt will continue to be, the issue to be resolved is the determination of the possible uses of traffic information in the cockpit which will produce the safest and most efficient ATC system in the future.

c. TERMINAL AREA GUIDANCE FOR RNAV AND PRECISION APPROACH AND LANDING.

By the year 2000, implementation of the Microwave Landing System (MLS) will have been completed in the terminal areas. This common Civil/Military system will be available to all aircraft at all airports.

The high accuracy and volumetric coverage of the system will allow considerable flexibility in terminal operations and will make All Weather Operations a reality.

The precise signals of the MLS (elevation, azimuth, and distance) will provide inputs to RNAV systems, which will allow use of these devices for terminal navigation and a consequent more efficient utilization of the terminal airspace.

By the time period under consideration, on-board digital computers and autopilots will be the rule rather than the exception. These devices will provide the capability for using the MLS signals for curved descending approaches for noise abatement, path-stretching, obstacle avoidance, etc. The broad coverage of the MLS will allow slow aircraft to turn on sooner increasing runway capacity.

With the precise distance and azimuth guidance of MLS, the on-board digital computers can provide roll-out guidance and programmed deceleration allowing the aircraft to turn off at the most advantageous exist, thereby decreasing runway occupancy time.

Timekeeping will be greatly improved as the aircraft become equipped with sophicticated RNAV displays which project the future position of the aircraft based on past history. This, coupled with metering and spacing or time constrained flightpaths, will approach a minimum time track and consequent fuel conservation.

All of these items, RNAV, MLS, RNAV displays, etc., will also provide precise missed approach and take-off guidance.

To complete the highly efficient terminal air traffic management capability, a computer controlled ground guidance and control system could also be operational. Aircraft position would be detected and displayed along with other route, plan, destination, . . . and other vehicular information would be processed for optimum movement of ground traffic, including arriving, departing, and in-transit aircraft as well as other ground vehicles.

Integration of the sophisticated airborne equipment with the precision MLS guidance information, advanced communications techniques, and ATC procedures, along with the new and better surveillance and monitoring systems, into a closed loop system could allow the system to handle higher densities of traffic with greater safety, higher reliability, and at lower cost. The question of whether or not this will happen is not due to technical uncertainties but is dependent on the operational philosophy in the year 2000 system design.

d. MASS WEATHER DISSEMINATION TECHNIQUES.

There is sufficient technology available to meet the forecast increase in demand for flight services. To achieve this objective, however, requires that certain manual work functions be allocated to machine.

Likely candidates for the immediate assumption of some of the increased workload are the Pilots Automatic Telephone Weather Answering Service (PATWAS) and the Transcribed Weather Broadcast (TWEB) available on L/MF NAVIDS and VOR.

This technique, the use of mass communication media as the telephone and radio, is termed Mass Weather Dissemination.

It has been demonstrated in the New York City PATWAS test that improvements in an existing PATWAS did result in the significant transfer of workload from the one-on-one briefer to hardware.

The improvements provided several route oriented briefings in addition to a local area briefing.

Each briefing was accessed by dialing a unique telephone number. The briefing content was current, being updated hourly and more frequently if required.

Current PATWAS systems employ magnetic tape technology and suffer the disadvantages of the need for redundant systems for message access, and a separate telephone number for each briefing.

The PATWAS is a voluntary use system. It will work only if it serves the pilot and he wants to use it. To encourage its use, NAFEC is engaged in the development of a Mass Weather Dissemination Exploratory Engineering Model. This system employes digital technology for voice and system control functions. It is conceived to provide versatility and economy of operation. Some of the features provided are:

- Instantaneous message update.

- One telephone number access.

- Any briefing can be requested by any caller.

- Each caller acquires a briefing from the start.

- Automatic and manual message update.

The design objective of this system is to provide the pilot with one call service. The engineering model will provide each of five briefings to any of 20 telephone lines in any mix of briefing the line.

The major systems components are:

- A digital computer--this is the heart of the system.

- A disc message storage unit on which are stored the briefings.

- An encoder for converting the spoken work to digital numbers.

- A decoder for reconstructing the spoken word from the digital numbers.

- A system switching unit which connects the pilot to the recorded briefing. A flight plan recorder, or a FSS specialist.

- An Utterance Recognition Device (URD) programmed to recognize each of 27 separate words on eight telephone lines simultaneously.

The system works as follows:

- On being connected to the system, the pilot is presented with an introductor message and is asked to select from three options; namely, to be presented with a prerecorded briefing, to file a flight plan, or to speak to a specialist.

- If the pilot says "briefing," the URD recognizes this utterance and sends a unique code to the computer. The computer starts a message telling the pilot he can select from a North, East, South, or West Route Oriented Briefing or a general Local Area Briefing by saying the appropriate word at the cue tone. The computer then tells the URD to issue a cue tone and to listen for the subset of utterance North, South, East, West, or Local.

- If the pilot says "North," the URD recognizes this utterance and sends a "North" code to the computer. The computer then causes the North Route Oriented Briefing to be read to the pilot.

- At the completion of the briefing, the system asks the pilot if he wishes to file a flight plan or speak to a specialist. The computer then tells the URD to issue a cue tone and to listen for the subset "file," and "specialist." If the pilot says "specialist" the URD will recognize the word and send the "specialist" code to the computer. The computer will then direct the connection of the pilot to an FSS specialist. It is expected that the informed pilot will occupy very little of the specialist time.

- On completion of the transaction the specialist asks the pilot if he wishes to file a flight plan. If the pilot says "yes," the specialist asks the pilot to speak his flight plan following the cue tone and reconnects the pilot to the system.

- A cue tone is issued and the pilot records his flight plan. At the completion of the flight plan filing, the system recognizes silence and then asks the pilot if he wishes the flight plan read back to him. The computer tells the URD to issue a cue tone and to listen for the subset "yes" and "no."

- If the pilot says "yes," the URD sends the "yes" code to the computer which tells the flight plan recorder to rewind and play the last recording. The system then asks the pilot if he wants to file as read. The computer tells the URD to issue a cue tone and to listen for the subset "yes" and "no." If the pilot says "yes," the URD recognizes this utterance and sends the "yes" code to the computer which then completes the pilot's transaction with "thank you, have a good flight."

- Full use of the Mass Dissemination briefing technique will not be realized until an integrated mass weather briefing system is in operation. This integrated mass weather system could employ NWS radio, telephone, airborne radio, and noninterferring commercial broadcast TV wherein:

. NWS radio will provide local area briefings made available to the pilot around the clock and accessed via an inexpensive radio.

. Fixed Route Oriented Briefings can be provided via telephone access. It is expected that selected weather for selected locations not presented in the general route oriented briefing will be available to the pilot through system interrogation.

. Enroute briefing--what lies ahead--on his route or adjacent routes can be provided by TWEB.

. Noninterferring broadcast TV would provide the pilot with modified weather graphics and/or his own home teletype receiver.

. The integrated Mass Weather Dissemination System will provide more complete and less expensive service (over a long time) and minimize pilot/specialist contact.

e. ALTERNATE SOURCES OF ENERGY.

The FAA has thousands of facilities throughout the United States with power requirements that vary from just a few watts to over a megawatt. Energy requirements are expected to increase and the cost of supplying conventional energy forms to ATC facilities will increase rapidly. Advanced types of alternative energy systems include solar photovoltaics (direct conversion of solar radiation to electrical energy), wind (conversion of wind energy to electrical energy), and fuel cells (direct conversion of chemical energy to electrical energy). The capabilities of each source are summarized as follows:

(1) *Solar Photovoltaics (Photo-vol-ta'ics)* - The direct conversion of solar radiation to electrical energy. Presently most photovoltaic converters are essentially large surface semiconductor diodes, the most common type being made from silicon. Best suited for low power (< 1000 watts) applications. This device is currently being tested at NAFEC as a power source for a marker beacon.

(2) *Wind* - Wind energy is converted into the rotational energy of a shaft capable of driving a generator or alternator thus developing electrical energy. Best suited for low to medium (< 10,000 watts) power applications.

(3) *Fuel Cells* - These convert chemical energy directly into electrical energy by means of electrochemical reactions; energy of a fuel (hydrogen) and an oxidant (oxygen) are brought into contact with an electrolyte (hydrogen hydroxide for example) with the reaction creating a voltage difference. If a load is connected, a current will flow. They are best suited for large (< 10,000 watts) power applications but are not commercially available yet.

A solar photovoltaic system is presently being evaluated at NAFEC as a source of electrical power for a marker beacon. Since these beacons are low power and usually remotely located, it provides an excellent application for this type alternative energy system. Other applications and other energy systems are under study.

During the next 20 years we would expect that all new facilities and many of the older facilities could utilize some type of alternative energy system either as the primary power system or as the backup power system. In addition, the use of solar thermal energy to provide the heating and cooling of ATC facilities could also be a reality.

f. DATA LINK APPLICATIONS.

Air Ground Data Link is technically feasible today and will be widespread by the year 2000 in the form of a DABS data link. While the primary purpose of this data link is for ATC tactical commands and advisory, it may be possible for frequent aircraft users of the ATC system to install printers and displays to also receive routine messages of air traffic control, weather, NOTAMS, and flight plans. However, voice communications would still be required particularly by the small general aviation user. Complementing the data link applications will be the availability of computer output digital to voice synthesizers. This would be especially applicable for dissemination of weather and flight condition information for use by ARTCC's, towers (manned and unmanned), and by Flight Service Stations. Timely information, direct from computers, could be provided to the users and greatly reduce the ATC operator involvement and delays.

g. REMOTE MAINTENANCE MONITORING SYSTEM (RMMS) IN THE YEAR 2000.

As an integral part of data communications, a national remote maintenance monitoring system (RMMS) network will be the core of an efficient, cost effective ground system maintenance program. Computer based remote maintenance monitoring, embodied in a national network, will allow the FAA to keep pace with the expanding demands of aviation for additional services, while at the same time containing, or even reducing overall maintenance costs. RMMS, as the prime element of maintenance growth management, is in its infancy today. By the year 2000, its maturity as part of the ATC system will be assured. This network will, in an evolutionary manner, provide such features as:

(1) *Remote Certification* - Maintenance personnel will be able to monitor all facilities within a given defined sector from a central location and be assured of their performance without the need for daily or weekly visits.

(2) *Diagnostics* - Maintenance personnel will be able to remotely exercise a given system to establish performance trends and failure predictions, as well as isolate failures down to line replaceable units prior to visiting the facility, thereby minimizing down time.

(3) *Self-Healing* - With increased utilization of microprocessor, large scale integration, and sophisticated assembly language, critical mode equipment failures will be diagnosed and repaired on-site without human intervention, thereby providing an additional margin of system availability and, thus, safety.

(4) *Data Logging* - All administrative functions related to ground navigation, communication, and surveillance systems will become a function of the RMMS, including MTBF, MTR, and availability. By linking in a hierarchical manner, this data will be available to Regions and Headquarters personnel for their use in planning and control.

h. AUTOMATED TERMINAL SERVICE.

The Automated Terminal Service concept offers the potential of (1) providing additional safety at presently noncontrolled airports and (2) providing cost savings by delaying the installation of towers at some airports. The feasibility system developed by FAA and presently being evaluated at NAFEC has three major elements:

- A short range ($\sim$ 15 nmi) beacon radar located at the airport to provide tracking and identify on transponder equipped aircraft.

- A minicomputer to process this data and make decisions about the traffic situations, and

- A voice response system (VRS) to generate VHF voice messages based on the results of the computer processing and to record aircraft call signs, supplied by the pilot, for use in the messages.

The pilot establishes communications with ATC, declares his intentions, and identifies himself as VFR or IFR by a log-in procedure. Essentially, the pilot, upon entering the ATS surveillance area, squawks the published discrete airport code and tunes to the airport's "log-in" frequency. ATS acknowledges the pilot's log-in attempt and requests the pilot to speak a brief (3-5 seconds) aircraft identification into his microphone. ATS records the ID, repeats it for pilot verification, and finally assigns the pilot a discrete transponder code. The pilot is now logged in and all further communication with him will include this aircraft ID. After log-in, an ATIS-like message would automatically be provided to the pilot.

The test bed is a functional model of ATS, but does not reflect production equipment. It is currently being exercised in a controlled environment at the NAFEC.

Systems testing and feasibility demonstration will be performed in 1977. The feasibility system at NAFEC was constructed of all off-the-shelf hardware. Aside from reduction in overall size and the replacement of the mechanically rotating antenna with an electronic scan antenna, the state-of-the-art can provide the following improvements:

- Inclusion of a voice recognition feature along with computer generated response so as to allow direct pilot communications with the system.

- Addition of intonation and emphasis in the VRS to improve the overall intelligibility of the advisory.

- A surveillance feature to allow for transmission of pertinent traffic to be displayed on a pilots weather scope or other ATSD.

- The capability to initiate and terminate through the ATS of VFR and IFR flight plans.

- The transmission of weather data obtained from local weather sensors (barometer, anemometer and wind vane, ceiling, temperature, and visibility).

The role of ATS in an ATC system for the year 2000 will not be constrained by technology but will be determined by the operational philosophy against which the future system is to be designed.

j. SATELLITE COMMUNICATIONS.

The widespread use of synchronous satellites for communications by the year 2000 can certainly be a reality. A pair of synchronous satellites, positioned in both the Atlantic and Pacific oceans, could provide a minimum of five or six channels for data communications and surveillance purposes. This would provide a more controllable ATC environment in oceanic areas with a projected accuracy of surveillance of 2.5 miles or less and an immediate data communications response. This can reduce the current separation requirements for remote areas significantly and greatly increase the air traffic control capacity in those areas.

There are many other ATC applications for synchronous satellites. These include monitoring of over 15,000 remote sites of FAA. In lieu of inflexible and costly telephone lines, a synchronous satellite channel could monitor navigational air locations by pooling each location in turn for an indication of status. Information received can be distributed to the exact required locations, significantly reducing time and cost of data distribution. Synchronous satellite channels can be employed as emergency backup in the event of land line failure center-to-center, tower, FSS, etc. This redundant path of communication could greatly improve reliability statistics. Synchronous satellites could also be employed for mass dissemination of weather. Aircraft would be able to tune to single channel and receive printouts of weather conditions and a list of all NOTAMS which could be updated very rapidly from a single ground transmitting station.

k. SATELLITE NAVIGATION.

By 1984, a 24 satellite GPS/NAVSTAR system has the potential to provide a worldwide 3D navigation capability. The role of satellites for navigation in the year 2000 is not dependent on satellite technology but awaits answers to the following questions:

- Is the cost to both the provider and the user less than competitive solutions (second generation VORTAC plus Omega both with a 4D RNAV capability)?

- International acceptance.

- The degree to which the functions of navigation, communication, and surveillance should be included in a single system.

l. ADVANCED COMPUTER TECHNOLOGY.

The computer architecture of the NAS Stage A system was specified in the mid-1960's, and was based upon the most advanced computer technologies commercially available at the time. The general architectural characteristics of that system were also used in ARTS III and are listed below:

- Use of multiple computer elements and multiprocessing/programming techniques as a means of obtaining the necessary computer capacities and of achieving continuous system operability in spite of component failures.

- Expandable storage capacity to accommodate system growth and for economy in tailoring system installations to specific facility requirements.

There are, however, practical limits to which the basic systems can be "expanded" without violating the initial architectural constraints.

Both the NAS Enroute and ARTS III systems will face this problem within the next decade. The development plans for both programs indicate that an increasing number of functions will be automated as part of the upgraded third generation ATC system. Adding these advanced functions to the system will result in increased data processing loads.

Again, technology appears to be no problem. Few technical areas have advanced as rapidly during the past decade as computer technology and the pace is not likely to diminish during the next decade. Light pipes promise high speed transfers of data as do many other batching techniques being tried in various systems. Bubble memories are presently being manufactured and might be one of the devices that will be developed in the next few years to expand storage system. If these developments occur, they will lead not only to distributed processing, but to a further dispersion of processor to a sensor location. This will directly affect the data base and communication system.

The weight, size, cost, power needs, and reliability of the present hardware elements will allow dispersion of system elements to remote locations: aircraft, satellites, sensor points on runway and ground-based locations. The advent of one chip 16-bit processors with the instruction power of what used to be a minicomputer and the minicomputer with 32-bit words and the addressing power that this implies indicates that it has become difficult to talk of micromini-maxi and to be sure of the cost of electronic logic. It is the electro-mechanical devices that are the cost part of present systems. To the degree that these electro-mechanical devices can be eliminated is the limit on the cost flexibility and reliability of the system.

The question is not whether the existing computer system can be expanded to meet future requirements, but rather it is one of deciding how and when to modify existing computer systems to meet the expanded requirements of the future, and in selecting new computer designs to match the requirements of new systems.

3. UNANSWERED QUESTIONS ON OPERATIONAL PHILOSOPHY OF THE ATC SYSTEM IN THE YEAR 2000.

In planning an ATC system for the year 2000 it is not enough to consider only what technology has to offer and ignore "... the realities of today ...." Today's ATC system is large and complex and is a result of evolutionary changes over a period of 40 some odd years. The investment on the part of system providers, operators, and users is enormous and along with international considerations cannot be ignored. In spite of what technology can offer either today or tomorrow, change will come very slowly and must of necessity evolve from what is in place today.

In approaching the design of an ATC system for the year 2000, FAA has concluded that major increases in capacity which will accommodate commercial aviation and the growing number of general aviation operations at reasonable cost to the participants with a high level of safety, require not new technology, but consideration and solution of a series of difficult questions on operational philosophy. These questions are not new, but they must now be faced and attempts made to answer them, if an ATC system concept for the year 2000 is to emerge with high confidence of producing useful results at reasonable cost. The questions should not be answered by FAA alone because the consequences affect airport operators, general aviation, business aviation, and airlines in very direct ways. Some of the questions will arouse controversy and some may be unanswerable except by policies established by the Government. But the answers to these questions are required if FAA is to structure the new directions for an E&D program which based on existing technology can support the ATC system design for the year 2000.

FAA, on June 8, 1977, reviewed with the Subcommittee on Transportation, Aviation and Weather, House Committee on Science and Technology some of the issues which must be addressed. Several of the more critical issues and questions presented by FAA are summarized in the following six areas:

a. AIRPORT CAPACITY CONSTRAINT.

One of the major questions dealing with the airport capacity issue is, "Are there cost-effective limits beyond which adding small incremental and costly technological gains to major airports are no longer cost-effective in comparison to developing new airports?"

Twenty-two airports are expected to have peak hour delays of one-half hour or more by year 2000 without implementation of system improvements. The products of the current E&D programs will help alleviate this congestion. However, the current program yield in capacity is smaller than the expected forecast in demand. How much is worth doing?

b. AUTOMATION OF ATC.

There are four questions dealing with the further automation of both the terminal and enroute ATC system.

- How far *should* we go toward automating the functions now performed manually by air traffic controllers in order to increase his productivity so that we can handle the large growth in forecasts without a commensurate increase in cost of operating the system. Some experts conclude that, sometime before the end of this century, we could reach a point where it just would not be possible to effectively use more controllers and that the capacity of our enroute airspace could be "controller-limited." However, as we attempt to automate the control decision-making process, a whole series of questions must be faced. For example: How, in a highly automated environment, do we keep the controller involved and stimulated?

- Next, as we move to higher levels of automation, the system may allow a controller to handle significantly more traffic than he is capable of handling today. What, then, happens if the automation fails? To what extent can the controller be expected to take over? To what extent do we have to rely on redundant equipment both on the ground and in the air?

- Third, if we find that we cannot design a system so that controller can take over in case of a major failure, can we design a system that is failure proof? Since in practice there is no such thing as a completely failure proof system, how far must we go in that direction and what are the costs?

FAA is currently doing work to identify which of the controller functions can be automated.

One effort underway uses a typical enroute sector to learn about the problems and possibilities of such automation in a stimulated environment. However, much work remains to be done before one can be confident that the improvements that we can demonstrate in a laboratory environment can be introduced into the operational system.

- The last question deals with the role of "primary" radar.

We have now reached the point where the "secondary" radar is the one we rely on the most, i.e., "primary" radar is now a backup. The primary radar continues to provide information that we do not get from the secondary radar system--surveillance of thunderstorms and heavy rain cells, and surveillance of aircraft which do not carry transponders or whose transponders have failed. There is a continuing need for primary radar for air defense requirements. The long-term roles of primary radar in the evolving system, to determine whether it should be different in the future, and the technology impact of a changing role must be examined.

c. MAXIMUM FREEDOM OF AIRSPACE USE.

We all know that as traffic density increases, the collision risk also increases--so there is an additional need, at certain density levels, to require systems in aircraft, or new airspace procedures, to assure the airspace remains safe and efficient. Yet many airspace users either cannot afford expensive airplane systems or feel they do not benefit enough to require some of the new services being offered. The best arrangement to provide the necessary safety services in a way that preserves maximum freedom of airspace utilization must be found.

d. ROLE OF THE PILOT.

Next are a group of issues or questions which have long been debated in many places. There is a possibility that in order to achieve optimum utilization of limited airport capacity, while at the same time achieving the highest level of fuel conservation, the degree of ATC system control over the aircraft intending to use certain of the busiest airports should change. It may be that a centrally managed automatic system in which the degree of control over the aircraft is increased may yield the most efficient operations. Yet the whole idea of more control of the aircraft from the ground is repugnant to many pilots and aircraft operators. There are some indeed who feel that control should be less centralized than it is today.

The potential benefits of the concepts of tighter central management control--as well as less control--to establish the best direction for future development of optimum airport usage must be examined.

Closely tied to this question is the current and potential division of responsibility between the controller on the ground and the pilot flying the airplane. There are many views here--there are strong views that giving the pilot more information and more responsibility for maintaining safe separation from other aircraft can provide a more efficient total system. The present air traffic control system utilizes a carefully structured division of responsibility between controller and pilot. The question is whether the distribution of responsibility is now optimum or whether a different approach to the assignment of responsibility--moment-to-moment--would yield a better system.

The third question assumes that increases in the automation of the ATC system will require changes in the information presented to the pilot. The questions of how much information the pilot needs in order for him to be comfortable in a more automated environment, as well as the best ways of providing such information must be studied.

e. <u>RATIONALE AND TIMING FOR NEW TECHNOLOGY</u>.

The potential use of satellite technology in the evolving ATC system has long been under consideration. The basic view FAA has taken has been to study satellite possibilities for implementation when this technology can provide a service FAA and the users need at a cost which is competitive with other solutions--and that cost must be considered both as it affects the Government itself and the users.

A closely related question on the potential use of satellite technology concerns the degree to which the functions of communications, navigation, and surveillance should be included in any single system. It is not obvious that integration of these three functions is necessarily the right thing to do.

After these questions are studied and answered, technology advances in the areas of Computer Image Displays, Color Displays, Computer Voice Entry, Computer Voice Recognition for mass weather dissemination, alternate sources of energy, satellites, cockpit display of traffic information, advanced computer architecture, automated terminal services, etc. applies and only then can be intelligently selected for use in a future ATC system design. Only after this is done will a description of ATC in the year 2000 have any meaning.