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Quarterly Technical Summary

Air Traffic Control

15 August 1970

Prepared under Electronic Systems Division Contract AF 19(628)-5167 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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INTRODUCTION

During this period we have continued our efforts to evaluate quantitatively the capabilities and limitations of the systems, procedures, and instrumentation utilized for ATC. The problems in busy terminal areas resulting from the increased volume of traffic are receiving special attention. In addition, determination of the basic requirements for data acquisition and communications necessary to alleviate the current critical situations and for an eventual fully automated system are proceeding. Field measurements of the current beacon interference environment have continued, and development of an experimental discrete-address beacon has been started.

A new activity is directed toward defining and evaluating the impact that a data-linked cockpit display of Automated Radar Terminal System (ARTS) information could have upon terminal area capacity. Also under study is the application of a laser beam alerting system at Logan International Airport to increase the usefulness of Runway 4R.

Staff and funding constraints have limited the current effort and will continue to do so until added support is obtained from DoT/FAA. Our increased understanding of the current ATC system and the developmental objectives has reinforced our belief that the capabilities and experience of the Laboratory are ideally matched to this national problem.

15 August 1970

H. G. Weiss
Head, Division 4

Accepted for the Air Force
James W. Malley
Acting Project Officer

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AIR TRAFFIC CONTROL

I. SUMMARY

The major focus of the Lincoln Laboratory Air Traffic Control program continues to be the development of an improved surveillance and communication capability adequate to the needs of an automated air traffic control system. The goal of this effort is the system design, prototype hardware development, and functional testing and demonstration of a discrete-address beacon transponder system with integral data link. It is recognized, however, that full-scale implementation of such a system will require a period of 10 to 15 years; consequently, an important part of our program is the development and demonstration of improvements to the existing Air Traffic Control Radar Beacon System (ATCRBS) so that it can provide adequate capability during the transition to a discrete-address system. Current status of these efforts is reported in Section II.

Two additional projects have been initiated during this quarter. An interdisciplinary team is now evaluating the utility of a cockpit display of selected information from the Automated Radar Terminal System (ARTS) horizontal situation display. Our initial objective is to determine whether the availability to the pilot of these data in real time would influence his ability to operate more effectively in the terminal area. Operational research studies to evaluate the effect of this class of system on terminal area procedures, safety, controller and air crew workload, and terminal area efficiency have been started. A computer simulation of several possible cockpit situation displays is now functioning, and this will be "flown" in a cockpit mockup to study display parameters and cockpit workload. This phase of the program is being performed by the Electronic Systems Laboratory and the Aeronautical & Astronautical Department of M.I.T. and is reported in Section IV.

Secondly, we have proposed to evaluate a laser warning system to alert the tower controllers at Logan International Airport of potential conflicts between aircraft approaching Runway 4R and tall ships in the adjacent shipping channel. A technical program to test this system has been developed and is reported in Section V.

II. BEACON SYSTEM DEVELOPMENT

A. ATC Radar Beacon System (ATCRBS) Improvements

1. Introduction

A study to determine quantitatively the effects that modifications of the ATCRBS could have on improving the flow of air traffic has begun. Many different improvements are technically feasible, but a quantitative assessment is needed to evaluate the cost effectiveness of various improvement options. This study is divided into two major tasks. First, the flow of air traffic must be related to the surveillance and communication capability; this implies that the quality of the surveillance data and the communications demands must be established for both the existing and future air traffic control environment. Second, the performance of the ATCRBS (with modifications) must be evaluated in terms of the many system parameters and operational constraints.

The time span of a development program for ATCRBS improvements suggests that the implementation of National Airspace System (NAS) Stage A and ARTS II, III, and IV will be well under way, and that traffic controllers will be functioning in a semiautomatic ground environment.

Thus, an important part of the first study task is the determination of surveillance data requirements to insure proper functioning of NAS/ARTS and the evolutionary steps toward further automation of the control function.

To facilitate the acceptance and implementation of ATCRBS improvements, significant changes of the aircraft transponder should be avoided. However, the possibility of a discrete-address transponder and digital data link capability being added to the basic ATCRBS system deserves careful consideration. This improvements study will therefore consider ATCRBS modification options to provide a discrete-address data link capability that will be compatible in an environment that includes unmodified airborne and ground equipments.

2. Classification of ATCRBS Problems

The basic function of the currently operational ATCRBS is to detect, locate, and identify beacon-transponder-equipped aircraft within range of a ground interrogator. The data quality provided by the ATCRBS can be characterized by:

- (a) Detection and false-alarm probabilities,
- (b) Range and azimuth accuracy of detected targets,
- (c) Ability to resolve two closely spaced beacon targets,
- (d) Identity code and altitude readout probability.

The data quality, in turn, determines the accuracy with which targets can be tracked and the continuity or reliability of the tracking.

There are a number of effects that limit the ATCRBS data quality as characterized by the quantitative performance measures given above. These problems may be traced to the following basic causes:

- (a) Variability of the signal-to-noise ratios in the up- and down-links due to antenna pattern gain variations, multipath propagation, interrogator siting, and aircraft attitude,
- (b) Multipath propagation which results in distortion of the interrogation and reply signals and ghost signals (reflections),
- (c) Signal formats and tolerances which limit both accuracy and resolution of the system,
- (d) Channel congestion in both the up- and down-links resulting in missed, garbled, and invalid interrogations and replies,
- (e) Non-ideal data processing resulting in degradation of data quality.

The rate of change of the physical configuration of the RF channel between the interrogator and an aircraft is so slow that the effects due to the first two basic problem causes are effectively invariant during the time that it takes the interrogator antenna main beam to sweep past the aircraft. These slowly changing effects that are invariant interrogation-to-interrogation can result in erroneous or low data on particular aircraft for several successive antenna scans. The slow effects can be limited most effectively by antenna design and location changes both on the aircraft and on the ground.

Changes in the basic ATCRBS signal format to improve system performance may not be practical if they require changes in the transponder design, although tightening signal tolerances might be possible. The only practical recourse to combating the limitations of the current format appears to be the use of more advanced data processing.

Interference among interrogations and replies usually involves different interrogator or aircraft on successive interrogations. Hence, these effects are effectively independent during the interval that the interrogator beam sweeps past an aircraft. Interference effects require careful management of the interrogator environment and advanced data processing to obtain the best possible data quality for a given interference environment.

3. Program Outline

To evaluate the effect of surveillance data quality on the flow of air traffic, it will be necessary to determine the data input requirements that will insure proper functioning of the basic NAS/ARTS equipment as well as the additional needs to support higher levels of automation of the control function. This data requirements study will include modeling, analysis, and perhaps simulation of the basic functions of the air traffic control system (such as ground-controlled collision avoidance, metering and sequencing for landing, monitoring approaches to closely spaced parallel runways, etc.). The data requirements for each of these functions will be found assuming ideal, unconstrained data processing, which will then provide a useful standard of comparison in evaluating input requirements of NAS/ARTS hardware and software, as well as alternate implementations.

The evaluation of ATCRBS modifications can then be made on the basis of their effect on data quality as well as the data requirements for effective air traffic control. Therefore, a performance analysis of the ATCRBS will be made to provide a quantitative assessment of data quality for various system parameter changes. Again, an ideal, unconstrained data processing system will be assumed for this performance analysis to provide insight into the fundamental limitations on the ATCRBS performance as well as to provide a standard of comparison with which to evaluate non-ideal, practical data processing systems. This analysis will also evaluate as modifications of the basic ATCRBS the addition of a discrete-address transponder and air/ground digital data link capability. Both the data requirements analysis and the ATCRBS performance analysis are now under way. Some interim analytical results will be forthcoming in the near future.

The capacity of the ATCRBS must be defined in terms of some minimal acceptable performance level. The ATCRBS performance analysis, together with air traffic forecasts, will provide estimates of the ultimate capacity and lifetime of the ATCRBS. Various components and subsystems for the ATCRBS resulting from design studies must be evaluated on the basis of their effect on over-all system performance as well as cost. Thus, the data requirements analysis and the ATCRBS performance analysis provide basic inputs to the formulation of a meaningful ATCRBS improvements program.

B. Surveillance Data Requirements for Ground-Based Collision Avoidance

An analysis of the surveillance data quality required to support an automated ground-based collision avoidance function has been made. The concepts of warning time, prediction uncertainty, and hazard region have been adopted from similar analyses of the airborne Collision Avoidance System (CAS) problem. In addition, the present analysis has emphasized the effects of measurement errors and the statistical characterization of over-all system performance. The warning problem is treated from the point of view of decision theory, in which the noise effects are traced back through the collision assessment and tracking functions to a simple model of the surveillance data errors.

Two measures of system performance are developed: one appropriate to highly organized traffic under Area Positive Control (APC), and another appropriate to highly disorganized traffic,

as in the Intermittent Positive Control (IPC) of VFR and mixed traffic. In both cases we demand that the system have a very small probability of failing to detect a valid collision threat. For organized traffic we demand that the system also have a very small probability of false alarm for aircraft passages whose miss distance is comparable to the normal spacings assigned by ATC. In this way we are able to specify performance quantitatively and develop expressions for the required data accuracy in terms of parameters such as warning time, track age, data rate, maneuver bounds, etc. To treat the IPC problem, we use a gas model and study the rates of occurrence of valid and false warnings. It is shown that these rates depend upon the characteristics of the CAS through the effective cross sections for valid and false warnings, and the ratio of these rates is independent of the gas model employed. This leads finally to the notion of "efficiency," the percentage of total warnings which are valid, in the context of random encounters. By assigning a value to the system efficiency, we can again obtain quantitative requirements on data accuracy in terms of the other system parameters.

In general, it appears that a ground-based automatic CAS can be made to work in an organized traffic environment with basic positioning accuracies of the order of 100 feet, while the IPC function requires nearly an order of magnitude greater accuracy. The results are, however, extremely sensitive to certain parameters and assumptions and are best interpreted as trade-off relations among system parameters. Detailed results will be presented in a report now in preparation.

C. Discrete-Address Interrogator Control

Studies on the computer control aspects of an interrogator for a prototype discrete-address system have been initiated. The work to date has been concerned with the preliminary organization of the control tasks. Future work will be concerned with the specification of a computer and peripheral hardware, software development, and experimental tests. The control tasks are being organized on the assumption that the interrogator antenna is a single dish rotator with monopulse capability permitting azimuth determination on a single reply. The computer controls the scheduling and processing of returns for interrogations of both conventional and discrete-address beacons. The surveillance data and aircraft-to-ground messages derived from the interrogations will be sent to ATC computers over phone lines.

Preliminary studies of the functions to be performed by the computer with respect to discrete-address-beacon-equipped aircraft are almost complete. However, numerous details must be resolved before estimates of the required computer capacity can be made. The interrogation scheduling, including re-interrogation in the event of a missed or garbled reply, will be handled on a range-ordered basis for aircraft in the antenna beam. Tracking will be performed by rho-theta-altitude algorithms using fixed-point arithmetic. This tracking is rough but adequate for interrogation scheduling.

D. ATCRBS Interference

A major goal of the interference investigation is to determine whether a discrete-address interrogator/transponder system can operate on the same frequencies as the existing ATCRBS.

1. Interference on Up-Link

Each of the present interrogators transmits approximately 0.1 percent of the time in the 1030-MHz band. Since present interrogators are not synchronized, their transmissions will act

as interference to up-link signals from a new interrogator which transmits discrete address codes and/or data to aircraft with discrete-addressable transponders. The communications channel to each of these aircraft will be subject to interference approximately $(0.1)n$ percent of the time, where n is the number of conventional interrogators simultaneously interrogating the aircraft. Studies to date indicate that proper signal design will permit a discrete-address system to co-exist with the present system on the up-link centered at 1030 MHz.

2. Interference on Down-Link

The interference on the down-link at 1090 MHz presents a substantially more severe problem. Each aircraft equipped with a conventional (ATCRBS) transponder is a potential source of interference; the number of aircraft that can cause interference in the receiver of a discrete-address interrogator can be quite large. The severity of the interference is a function of the number and geographic distribution of aircraft with conventional transponders, the number of conventional interrogators which interrogate these aircraft, characteristics of the antenna pattern of the discrete-address interrogator, and characteristics of the site of the new interrogator, particularly the size of sources of reflection multipath.

Our interference investigations have focused on determining the severity of today's interference environment and on developing analytical models for prediction of the future level of interference. We have constructed and installed instrumentation in a mobile van to record the interference level that exists in typical ATC environments. Using a receiver that accepts signals at 1090 MHz, we are counting the number of transponder signals received with an omnidirectional antenna. Returns received with power above a particular threshold level are counted. Data are taken for various values of this threshold level. These data are related to the average level of interference that would be seen by a narrow-beam antenna which is mechanically or electronically rotating and provides bounds on the maximum levels that would be observed.

Initial tests have been carried out at Hanscom Field and Logan Airport and are currently in progress in the New York area.

E. Discrete-Address Interrogator Antenna

The evolution of the present ATC Radar Beacon System into a discrete-address beacon/communications system will require the use of more sophisticated interrogator antennas if a high degree of communications reliability is to be obtained and if the accuracy of the azimuth angle measurement is to be significantly improved. In the existing system the azimuth angle measurement is made by determining the mid-point of a series of beacon replies as the antenna scans by the target aircraft. Each target is interrogated, and replies, many times per scan. In a discrete-address system, it is desirable to interrogate/communicate with an aircraft only once, or at most only a few times per scan, in order that the system have the capability of handling a large number of aircraft. To perform a highly accurate azimuth angle measurement on one or a small number of replies requires the use of an angle-of-arrival measurement technique generally referred to as monopulse or simultaneous lobing.

The present interrogator antenna has a very small vertical aperture. Consequently, a large part of the beam illuminates the ground, causing vertical lobing due to ground reflections and off-angle responses due to reflections from buildings and other obstructions. Through the use of antennas with substantial vertical aperture, one can cause a sharp cutoff of the lower edge of

the beam, thus reducing the amount of reflection from the ground and low-elevation objects. Alternately, several narrow elevation beams may be used independently, providing discrimination between high- and low-angle targets. Further sophistication of the antenna will allow the beam to be scanned in elevation in order to lift its lower edge over obstructions or irregular terrain. (Limited elevation scan is being considered by the FAA as part of the development of a phased-array antenna for ATCRBS.)

A study has been started to determine the most effective way of incorporating additional vertical aperture into the beacon system, and of introducing other improvements such as monopulse capability which will increase the system's data collecting ability and increase accuracy. Both rotators and phased arrays will be considered. Some questions to be answered are:

- (1) Can the vertical aperture of the present radar antennas be utilized, by employment of a new feed system, to provide improved beacon performance as well as the present radar function without degrading radar performance?
- (2) If the answer to (1) is no, what is the best radar/interrogator antenna design which will allow adequate radar performance and achieve the desired improvement in the beacon interrogator?
- (3) What is the practical limit to rotator antenna designs which will provide increased data rate and improved elevation coverage as recommended in the Air Traffic Control Advisory Committee (ATCAC) Report, and how do the costs and capabilities of such rotating antennas compare with a phased-array interrogator?
- (4) What is the most suitable design of a phased-array interrogator and what are some of the cost/performance trade-offs among the various techniques available for beam control in such an antenna?

F. Interrogator Antenna Siting

Analysis methods for determining the effects of various objects near the site of an interrogator have been developed. The effect on azimuth accuracy of objects near or in the line-of-sight path from the interrogator to the aircraft can be determined by using diffraction theory. The amplitude of a side or back lobe in the interrogator antenna pattern caused by a reflecting object can be computed by using the methods developed. A smooth spot on the ground within the main beam of an interrogator will cause a large specular reflection. The relation between the size of this spot and the amplitude of the reflected signal has been derived. This relation can also be employed to determine the size of reflections from buildings or other objects. The trade-offs between locating an antenna high or low have been investigated, and the advantages of employing a large vertical aperture have been examined. The results of the signal multipath measurements on an air-to-ground link described previously* have been useful in checking the methods of analysis. The properties of the present ASR site at Logan Airport and a high, semi-rural site in Billerica, Massachusetts have been examined in detail.

G. Off-Boresight Monopulse System

The use of a single transponder reply for azimuth angle determination requires a monopulse system that can accurately measure angle-of-arrival on off-boresight targets. Major questions

* Air Traffic Control Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 May 1970), DDC AD-707137.

about such a system which have been studied in the past quarter are the type of signal processing to be used and the angular estimation accuracy that can be obtained.

The prior literature relating to the above was found to be sparse and directed only at the radar problem. A previously reported result* suggesting the possibility of "completely accurate" azimuth angle measurement off-boresight with an amplitude monopulse radar was shown to be incorrect. The discrepancy was traced to the evaluation of a key system parameter for which a new, simple, but rigorous method of evaluation was proposed and illustrated in several cases. The results alter a multiplicative constant in the on-boresight formula as well. In general, the present results apply to the beacon and the radar cases for the general variation of σ_{θ} with θ , which can differ considerably from prior theory; this point has been illustrated by a specific example. The work for the beacon case will soon be published.

The off-boresight angular estimation accuracy of amplitude monopulse beacon (as opposed to radar) systems has been considered. A theory was developed by cross linking the basic constraints of signal processing in the presence of noise and fundamental antenna effects such as mutual coupling between antenna feeds and minimal possible mismatches in antenna feed lines. The theory was extended in a direct fashion to the radar problem, since it had not been developed previously for this case. The choice of optimization criteria differs significantly for the search (off-boresight) and track (on-boresight) modes. While such criteria have been extensively considered for the tracking mode, there appears to be no discussion in the literature for the search mode. Reasonable criteria have been tentatively selected. Analytical and numerical results have been obtained for several cases and highlight the result that the optimum ratio of squint angle to beamwidth is dependent on the shape of the antenna pattern and appears to run about 20 to 25 percent higher than the optimum ratio for the track mode. The preliminary conclusion from the work is that off-boresight monopulse operation is quite feasible in the ATC beacon system, given certain reasonable constraints. An internal memorandum on this work is in preparation.

H. Solid State RF Power Source for ATC Transponder

Investigations are under way to define areas of potential improvement in ATC transponder hardware consistent with the goal of adding a future discrete-address and data-link capability. One important improvement which can be defined immediately and relatively independently of systems considerations is the conversion of the transponder transmitter to all solid state components. A solid state transmitter promises higher reliability, better efficiency, and a potential size reduction sufficient to enable the transmitter to be collocated with the antenna, thereby eliminating several dB of cable loss. The technology has advanced so that sufficient peak power is now available from either high-power microwave transistors or high-efficiency mode avalanche (TRAPATT) diodes. Both devices are being studied for this application. A two-stage transistor amplifier has been constructed which produces over 70 watts of peak power at a frequency of 1090 MHz. The pulsewidth is 10 μ sec with a repetition rate of 1000 pps. The amplifier uses a single Microwave Semiconductor Corporation Type 1100 power transistor as the output stage. The gain per stage is about 9.5 dB. The bandwidth is about 30 MHz. Future work with this amplifier will include measurements of the modulation and spectral characteristics of the circuit and an accurate measurement of the transistor S-parameters to allow for the design of a miniature and easily

*S. Sharenson, "Angle Estimation Accuracy with a Monopulse Radar in the Search Mode," IRE Trans. Aerospace and Navigational Electronics ANE-9, 175-179 (1962).

reproducible version of an amplifier which includes power combiners and is capable of integration into the transponder antenna.

A program for studying TRAPATT diodes as power sources for ATC transponders has been outlined. Considerations of device complexity, efficiency, and fundamental power limitations make the TRAPATT device a strong contender as a power source in this frequency band. The outlined study includes investigation of amplification circuitry and phase modulation techniques and will be directed toward eventual construction of a miniature integrated avalanche transmitter module.

III. ADVANCED SENSOR/COMMUNICATION SYSTEMS

Within Lincoln Laboratory there is a wide range of interest and development activity in advanced electronic systems involving radars, communication techniques, optics, signal processing, computer applications, phased-array technology, satellites, high-resolution measurements, and electromagnetic-wave propagation. While members of the Laboratory continue to express interest in and participate in meetings on time-ordered navigation and communication techniques, instrument landing systems, data links, and satellite applications, funding constraints have made it necessary to limit the work of the present program to a few specific tasks. It is hoped that added support can be received to incorporate more effectively the wide range of experience and skills within the Laboratory into the ATC development task.

IV. PROGRAM TO EVALUATE EFFECTIVENESS OF COCKPIT DISPLAY UPON TERMINAL AREA CAPACITY

One of the critical problems in ATC is increasing airport capacity, particularly during IFR conditions. The 3-mile minimum IFR separations in use during final approach result in substantially lower airport capacity than is achieved routinely under VFR. With the information currently available in the cockpit, closer IFR separations do not seem acceptable to the aviation community. However, more efficient terminal area operations should be possible if selected information available on the controller's scope were transmitted and displayed with minimum delay in the cockpit.

The concept of relaying to the cockpit information generated by ground radars and beacons has been tried by at least five different groups during the past 25 years. However, these earlier systems did not have clean computer-processed data or Mode C altitude information -- a capability just recently introduced. In addition, airborne display technology did not permit the essential data to be presented in an easily assimilated form.

By the mid-70's about 60 of the major airports will be utilizing the Automated Radar Terminal System (ARTS). This system will provide the controller with filtered and computer-tracked target data which will be marked with alpha-numeric symbols showing identification, altitude, and ground speed. In addition, it is now technically feasible to bring high-resolution data from the ARTS computer into the cockpit via a narrow-band data link. This information could provide the pilot with a real-time display of nearby traffic as well as information useful for area navigation.

As a result of discussions with FAA personnel, commercial pilots, and others in the air transportation industry, we have concluded that, with present technology and the introduction of ARTS into the terminal area, a cockpit display could be provided which should contribute to overall terminal area capability. In the planning for this class of system, it is critically important to select and optimize the data to be presented in the cockpit and to evaluate and refine the system under realistic pilot workloads.

The data relayed to an aircraft would enable the pilot to confirm that his altitude, air speed, and heading, as determined by ARTS from radar and beacon responses, were consistent with his onboard derived information. He could therefore, at all times, check the credibility of the remote display. With this check on system performance and with the absence of any delay in the information, the pilot might have the tool that he needs to operate with greater confidence during a landing sequence. In time, this may lead to the acceptance of closer spacings.

Three on-campus research groups – the Electronic Systems Laboratory, the Flight Transportation Laboratory, and the Man-Vehicle Laboratory – are jointly participating with Lincoln on this program in the following tasks.

A. Operational Research Studies

A program is under way in the Flight Transportation Laboratory to assess the operational utility of a cockpit display and to determine the effect that this capability could have upon terminal area separation, procedures, communications workloads, and air route structures.

B. Display Definition Studies

The initial simulated display is now operating on an ADAGE computer in the Electronic Systems Laboratory. This simulation program is designed to provide answers to questions such as: Should the display be heading oriented, runway oriented, or north stabilized? Should the display be stationary or cockpit centered? How much information should be presented? What symbology should be employed? What is the required refresh rate and brightness level? The versatility of the ADAGE computer will permit these and other configurations to be modeled and studied.

C. Human Factors Evaluation

The ability of a man to utilize a cockpit display will be related to his over-all workload. A human factors evaluation is being conducted by the Man-Vehicle Laboratory which has substantial experience in aircraft instrumentation design. The most appropriate method for evaluating the cockpit workload in an environment which has a situation status/area navigation CRT display is under study. Possible physiological measurements of pilot workload are being considered.

Areas that will receive attention during the next quarter include (a) implementation of a cockpit mockup of a jet transport aircraft including essential controls and display instrumentation, (b) initiation of studies to determine methods for selecting appropriate data from within ARTS for transmission to the cockpit, and (c) planning studies for a "brassboard" flight-test model of a cockpit display unit and data link.

V. WARNING SYSTEM FOR RUNWAY 4R AT LOGAN AIRPORT

Logan Airport does not employ the first 2500 feet of Runway 4R during IFR and night VFR operations because tall ships in an adjacent shipping channel could at times penetrate into the approach zone. While it is a trivial task to detect shipping in the channel by radar or other sensors, the desire is to discriminate clearly between ships which are not a hazard to approaching aircraft, i.e., those less than 80 feet above runway height. For those which exceed this level, the desire is to provide a reliable, fail-safe, low-cost, unattended warning system which would detect only those ships that generate a possible conflict situation. Once the tower had been alerted, these ships would then be tracked through the approach zone using the ASDE radar, and appropriate action would be taken with approaching aircraft to avoid conflicts.

To develop the parameters for an operational alerting system and to gather data on ship traffic, heights, etc., we propose to utilize two or more laser beams and appropriate data recording cameras sited across the narrow neck of the inner harbor. The initial stages of the project would be directed at an early solution of the night VFR problem. Follow-on effort would be directed toward improvements in the system to insure fail-safe operation under restricted visibility and low ceiling conditions.

The preferred technical approach utilizes low-power (1 to 10 mW) He-Ne lasers with audio frequency modulations. The transmitted laser beams will be expanded to 1° to 2° in order that these small equipment packages may be mounted on inexpensive antenna towers without loss of alignment due to wind or ice loads. The transmitted laser beams will have power densities that are consistent with proposed Massachusetts regulations for the control of laser hazards. The receiver system includes spectral discrimination which permits identification of the several laser beams. Ship height, direction of travel, and speed can be determined by appropriate positioning of the several laser beams, together with simple logic circuitry in the receivers. The geography of the airport-shipping channel area yields a number of suitable sites for the laser gates, having path lengths between 2000 and 4000 feet. The heights of the laser gates will probably be between 50 and 100 feet. The path heights and lengths offer a good possibility of achieving fail-safe operation under restricted visibility and low ceiling conditions.

After discussions with the Massachusetts Port Authority, FAA, and ATA representatives, Lincoln Laboratory proposed to conduct a feasibility experiment in the Boston Harbor area.

While awaiting acceptance of this proposal from the Massachusetts Port Authority, test sites have been selected, a technical plan developed, and detailed hardware requirements established.

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13. ABSTRACT <p>During this period we have continued our efforts to evaluate quantitatively the capabilities and limitations of the systems, procedures, and instrumentation utilized for ATC. The problems in busy terminal areas resulting from the increased volume of traffic are receiving special attention. In addition, determination of the basic requirements for data acquisition and communications necessary to alleviate the current critical situations and for an eventual fully automated system are proceeding. Field measurements of the current beacon interference environment have continued, and development of an experimental discrete-address beacon has been started.</p> <p>A new activity is directed toward defining and evaluating the impact that a data-linked cockpit display of Automated Radar Terminal System (ARTS) information could have upon terminal area capacity. Also under study is the application of a laser beam alerting system at Logan International Airport to increase the usefulness of Runway 4R.</p> <p>Staff and funding constraints have limited the current effort and will continue to do so until added support is obtained from DoT/FAA. Our increased understanding of the current ATC system and the developmental objectives has reinforced our belief that the capabilities and experience of the Laboratory are ideally matched to this national problem.</p>			
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