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JFK AIRPORT GROUND CONTROL RECOMMENDATIONS

R.RICCI, I.ENGLANDER, G.GAGNE,
A.PASSERA, J.VILCANS
TRANSPORTATION SYSTEMS CENTER
55 BROADWAY
CAMBRIDGE,MA.,02142

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TECHNICAL MEMORANDUM

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16. Abstract The object of this effort was to generate a detailed recommendation on what to do about the JFK Airport Ground Traffic Control Problem, including a review of STRACS, a Surface Traffic Control System. Problem areas were identified by direct observation of operations in the Kennedy Tower as well as by published position papers on airport operations. System alternatives were generated and evaluated against a set of performance criteria. The following alternative systems for use at Kennedy were considered: (1) improved bright display with retrofitted ASDE II, (2) new radar with bright display, (3) new tower with new radar, (4) new tower with multiple radars, (5) old tower with multiple radars, (6) fully automated STRACS with discrete sensors, (7) fully automated control with digital radar, and (8) an austere mode STRACS (Intersection Control).

The recommendations for JFK are detailed with associated schedule times and cost. In the appendices are described a listing of the JFKIA problem areas, the status of the STRACS system and radar based systems, and a review of the interim loop display system.

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I. INTRODUCTION

BACKGROUND

The objective of this effort has been to generate a detailed recommendation on what to do about the JFK Airport Ground Traffic Control Problem. In 1966, the FAA published a document entitled, "FAA System Requirements for Airport Surface Ground Control", in which it was declared:

> "The need is already urgent (for a surface traffic system) at high activity airports and will become more critical with the gradual reduction of approach minima down to complete all-weather operations. Development and installation should keep pace with the lowering of weather minima."

In the summer of 1967, because of the planned introduction of the B-747 aircraft into the JFK airport, the need arose for higher terminal structures to permit second level loading of these aircraft, as well as the need for more gate and total apron space. The higher terminal structures resulted in some cases in the obstruction of the lines of sight from the Control Tower to portions of the taxiway system. Also, the Airport Surface Detection Equipment (ASDE-II) was similarly obstructed. To provide the additional space needed for the expanded terminals and aprons, the inner and outer peripheral taxiways were then pushed out closer to the adjacent runways. This resulted in an inadequate distance between the outer taxiway and runways for the safe holding of all types of aircraft after landing.

At about this same time (late 1967 and early 1968), the JFK tower requested the building of a new control tower (approximately $10M)[1] to alleviate the line of sight problems due to the expansion of the unit airline terminals at Kennedy to accommodate the Boeing 747 aircraft. This request is still pending. The Port of New York Authority (PONYA) suggested the development of an electronic solution to the blind spot problem rather than a new tower. Consequently, in June 1967, the PONYA signed a contract with Airborne Instruments Lab (AIL) for an investigation of Airport Surface Detection Techniques for a Surface Traffic Control System ($70K). This AIL effort recommended that an optimum detector system that

[1]PONYA estimate

would meet the requirements of a Surface Tracking Control System at JFK Airport could be a moving vehicle detector system such as induction loops.

Based on the AIR effort, in March 1969, PONYA concluded that detection can be satisfactorily accomplished using induction loop detectors as the basic means and, therefore, issued a request for proposals to develop a Surface Traffic Control System (STRACS) for JFK. The objectives of this RFP were: (1) solution of line of sight problems, (2) solution to storage of long-bodied aircraft leaving the runways, (3) more efficient movement of traffic, (4) minimization of voice communications, (5) reduction of human ground controller workload, and (6) improvement of safety and efficiency of operations at continually lower visibilities. In the RFP, PONYA stated, "It is intended that the basic detection device to be used in the system is the induction loop detector."[1] In June 1970, PONYA awarded a contract to LFE for the development of STRACS ($400K). This effort is still in progress.

To serve during the period that STRACS has been undergoing development, PONYA and FAA cooperatively installed, in January 1971, an Interim Aid feasibility model (Blind Spot Indicator) for a small portion of the taxiway system at Kennedy Airport behind the Pan American Terminal, where the line of sight from the Control Tower is obscured ($200K). This Interim Aid system involves several loop detectors in the pavement and a display panel in the Control Tower to advise the controllers of the presence of aircraft. This system should not be confused with STRACS, since there is no visual signalling to the pilot, no alarm, priority on routing logic, and, therefore, no automatic control. The evaluation of this Interim Aid Device is still in progress.

AIRPORT OBJECTIVES

Airports form a vital link in modern transportation systems and their efficient operation is required in order to handle the large volumes of goods and people which daily pass through them. The high costs of airport construction, combined with mounting public opposition to increasing their number, particularly in metropolitan areas, has generated pressure to greatly increase the

[1] "Test Evaluation of Detectors and Loop Configurations Proposed for STRACS", prepared by AIL for PONYA, February 1969.

utilization and efficiency of existing facilities. This has principally been accomplished by increasingly automated methods of en-route control and guidance, by increasing the volume of airport operations, by the reduction of approach minima towards the goal of all-weather operations and, more recently, by the introduction of large-bodied aircraft, such as the B-747. The advent of the B-747 has, in turn, generated more problems directly related to its huge size and has served to identify the basic inadequacies of present systems of ground control. The congestion presently suffered by the larger, metropolitan area airports, such as Kennedy, is a direct consequence of the delicate trade-off between utilization, with limitations imposed by airport size and operating procedures, and cost, usually expressed in terms of safety, convenience, and direct expense.

ANALYSIS STRATEGY

It is desirable at the outset to establish the objectives of this analysis and to outline the methodology which will be used. The present ground traffic control system at Kennedy is alleged to be inadequate or deficient in certain respects. The complaints arise from operating conditions which exist on the taxiways, runways and ramp areas and which are aggravated during periods of peak operation and at times of reduced visibility. Many solutions to Kennedy's ills have been, or are being proposed, each with its own merits; however, due to limitations in the amount of resources available and, to some extent, on the long lead time required for the implementation of particular solutions, it is necessary to carefully examine the basic problems and establish priorities. These priorities are based on an evaluation of the comparative severity of the existing problems.

II. PROBLEM AREAS

A number of problem areas have been identified from pilot and ground controller interviews which have been documented by the LFE Corporation. Further sources of information include direct observation of operations in the Kennedy Tower, as well as published position papers on airport operations. The entire list, which may include several independent references to the same problem, is included as a separate Appendix A. For the purposes of this analysis, however, it has been useful to classify the problems with categories such as guidance, control, surveillance, communications, safety and miscellaneous. Further analysis revealed that certain problems were, in actuality, dependent on, or a consequence of other more fundamental problems. For example, complaints of pilot unfamiliarity with the airport creates a need for more detailed explanations by the controller which contributes to communications congestion which, in turn, increases the controller workload, leaving proportionately less time available for control decisions.

PROBLEM SEVERITY CRITERIA

As an aid in establishing the hierarchy of problem severity, the following criteria have been used:

Class 1 - Moderate Problem

1) causes extra aircraft stops or minor delays
2) requires close attention by pilot or controller
3) increases pilot or controller workload

Class 2 - Major Problem

1) causes delays that affect scheduling
2) requires continuous attention by pilot or controller
3) generates pilot or controller confusion

Class 3 - Severe Problem

1) jeopardizes life or property
2) limits further increases in traffic volume
3) requires close coordination by several controllers over extended time period
4) requires reliance on inadequate equipment

ENVIRONMENTAL AND OPERATIONAL FACTORS

Environmental and operational factors must also be considered in establishing comparative problem severity as some types of problems are aggravated by adverse conditions.

The main environmental factor to be considered is visibility which will encompass many other conditions, such as weather effects and day or night operation. Similarly, operational factors can be represented by the specification of light or heavy traffic. Heavy traffic will be taken to mean the density of operations which exist during the peak rush hour times.

PROBLEM SEVERITY WEIGHTING

Table 1 lists a smaller set of problems condensed from the full list in Appendix A. It is felt that this smaller, basic set represents the fundamental difficulties at Kennedy. Table 1 shows the comparative severity of each problem as well as the agency reporting it as not all agencies concerned with Kennedy yet agree on the exact nature of the problems at Kennedy.

EVALUATION OF PRESENT DEFICIENCIES

SURVEILLANCE

Most surveillance problems would be immediately resolved if the ground controller could be provided with augmented visibility of the airport environment. Recent terminal structure modifications have resulted in loss of line of sight from the Control Tower to portions of the taxiway system. On other parts of the taxiway system, particularly those areas which lie beyond the outer taxiway, the visual perspective from the Control Tower makes pin-pointing of aircraft position ambiguous. At night, these problems are aggravated by a multitude of fixed lights around terminals and other structures creating a background clutter against which the tracking of vehicle movements requires continuous concentration and attention. This need will be helped by augmentation of controller visibility and will be aided by the development of a no-clutter (unwanted reflections due to ground or weather returns), high resolution, electronic plan-view display showing in sufficient detail the airport surface and the relationship between aircraft and the taxiway/runway structure. The incorporation of aircraft identification may be desireable. Such a display would enable

TABLE 1. JFK PROBLEM AREAS

	PROBLEM AREA IDENTIFIED BY					PROBLEM SEVERTITY CLASS		
	TSC	ATA	PONYA	FAA EASTERN	FAA TOWER	CLEAR (Day)	WEATHER	TRAFFIC
SURVEILLANCE								
Position/Identification	x				x	1	3	2
Blind Spots	x	x	x	x	x	2	2	3
Visual Perspective	x	x	x		x	3	3	3
GUIDANCE						2	3	3
Marking, Signing	x	x	x	x	x			
CONTROL								
Taxiway-Runway Separation	x		x			3	3	3
Runway Crossing	x		x			2	2	2
Staging areas	x	x			x	2	2	3
Controller Workload		x	x	x		1	2	3
COMMUNICATIONS						1	2	2
Frequency Congestion	x	x	x	x	x	1	2	2

NOTE: Severity class; Moderate = 1, Major = 2, Severe = 3 the ground controller to quickly and accurately assess the current traffic situation without relying on inadequate visual sightings. It can be expected that this display would be useful for many years after the installation of a fully automated surface traffic control system by providing a backup capability, in the event of primary system failure, which is highly compatible with present day control procedures.

GUIDANCE

The present taxiway structure at Kennedy is the by-product of a series of major expansions in runway and terminal facilities. In this process, runways and taxiways have been relocated and sections of old runways have been adopted for taxiway service. Also, fillets have been added to many intersections to facilitate turning movements. The result has been a confusing intermingle of pavements of varying textures and contrasts. At the same time, identification of taxiways has not kept pace with construction with the result that taxiways and intersection markings need improvement. A common pilot complaint refers to some signs being placed such that it is impossible to discriminate between which of two adjacent taxiways the sign refers to. Some relief, however, is being obtained by the installation of a new type of color-coded, lighted retroreflective taxi guidance sign, double edge stripes for the edge of taxiways, and improvements in in-pavement lighting fixtures.

CONTROL

Problems in control at Kennedy are more complex and not as readily identifiable as those affecting surveillance and guidance. Symptoms of the problem are frequently expressed as data communications congestion and increased controller workload. These troubles are not the causes of the problem, but merely the effects. For example, the proliferation of large-bodied aircraft such as the B-747, has caused major changes in the taxiway structure to accommodate required terminal expansion. In some places, the separation between runways and the outer taxiway is insufficient to hold these large aircraft after they have turned off the runway. In addition, their large size often generates interference with adjacent intersections and taxiways. There are cases where aircraft are stopped to expedite B-747 and stretch DC-8 handling, such as when they exit a runway aircraft must be stopped on a parallel taxiway to allow the long bodied aircraft to get off the runway.

An automated control system utilizing control signals at intersections would provide considerable relief to the controller by freeing him of routine functions and leaving more time for basic communications, supervision and decision-making. The automated control system also would contribute directly to solving two related problems: runway crossings and lack of staging areas. While physical constraints on airport real estate preclude expanding staging areas, some functions can probably be provided by automated circulating of aircraft on unused taxiways while awaiting gate clearances. In summary, an automated control system for routing aircraft reduces controller workload, increases safety of operations in bad weather, eliminates the blind spot hazard and increases the capacity to handle traffic.

REQUIREMENTS

SURVEILLANCE REQUIREMENTS

Basic surveillance requirements may be met with high resolutions, no-clutter plan-view display. The display might include:

- .sufficient detail of the airport surface
- .the relationship between aircraft and the runway and taxiway structure
- .capability of identification of vehicles
- .the condition of all control signal heads
- .moving aircraft symbols to enable the controller to estimate aircraft position, velocity and direction

GUIDANCE REQUIREMENTS

- .the guidance system must clearly delineate the route
- .intersections should display Go/No Go information to the pilot

- the necessity for radio communication between the pilot and the controller should be reduced to a minimum.

CONTROL

- intersections should display Go/No Go information to the pilot
- staging areas should be provided or alternately, aircraft requiring staging should be routed so as not to interfere with other aircraft
- signals along the routes of large-bodied aircraft should be sequenced or otherwise programmed to preclude interference with aircraft on adjacent taxiways, runways, and intersections
- the programming of control signals should include provisions for closed sections of the taxiway structure so as to minimize the increase in routing distance and number of stops
- control of taxiing aircraft should be exercised with the minimum reliance on voice communications
- the control system should be operative at all times, including the worst expected weather conditions
- the control system should serve all runways, taxiways and ramp entrances

COMMUNICATIONS

- the capacity of available communications channels should be increased
- the system should have gate assignment and availability status information made available

III. SYSTEM ALTERNATIVES

SYSTEMS ANALYSIS METHODOLOGY

It is the purpose of this analysis to examine in detail the problems and complaints associated with operations at Kennedy and to attempt to determine the fundamental causes which form the basis of these problems. An immediate output of this analysis was a set of requirements to be satisfied. In very few cases, however, can satisfying all the requirements lead to a satisfactory solution as some requirements are clearly contradictory. The derived requirements may be useful when considered together with estimates of problem severity in establishing priorities. In this way some of the contradictory and unsatisfiable requirements can be eliminated. Next, performance criteria are used to evaluate proposed alternatives in an attempt to satisfy the remaining requirements. Applying the priorities then helps to narrow down the practical choices available.

The reader is reminded that successful application of the principles of systems analysis requires large amounts of data in order that the problems be clearly defined. Similarly, applying criteria to evaluate alternatives requires considerable experience and intuition in the absence of such analytical tools as simulation in order to arrive at reasonable estimates of system cost and effectiveness. Engineering judgment was applied in this case and many iterations of the analytical process shown in Figure 1 were required to arrive at the recommendations outlined in Section IV. Discussion in the paragraphs below of more than a few of the basic considerations affecting the choice of alternative systems is beyond the scope of this report.

PERFORMANCE CRITERIA

Before decisions can be made as to the most desirable or effective solutions to the Kennedy AGTC problem, it is necessary to agree on a basis for comparison of the various alternatives. This basis is obtained by evaluating each alternative against a set of performance criteria; thereby establishing a criteria for the expected benefits. The actual set of performance criteria is derived from subjective and intuitive considerations and from experience with similar situations. Selection of the following list of criteria

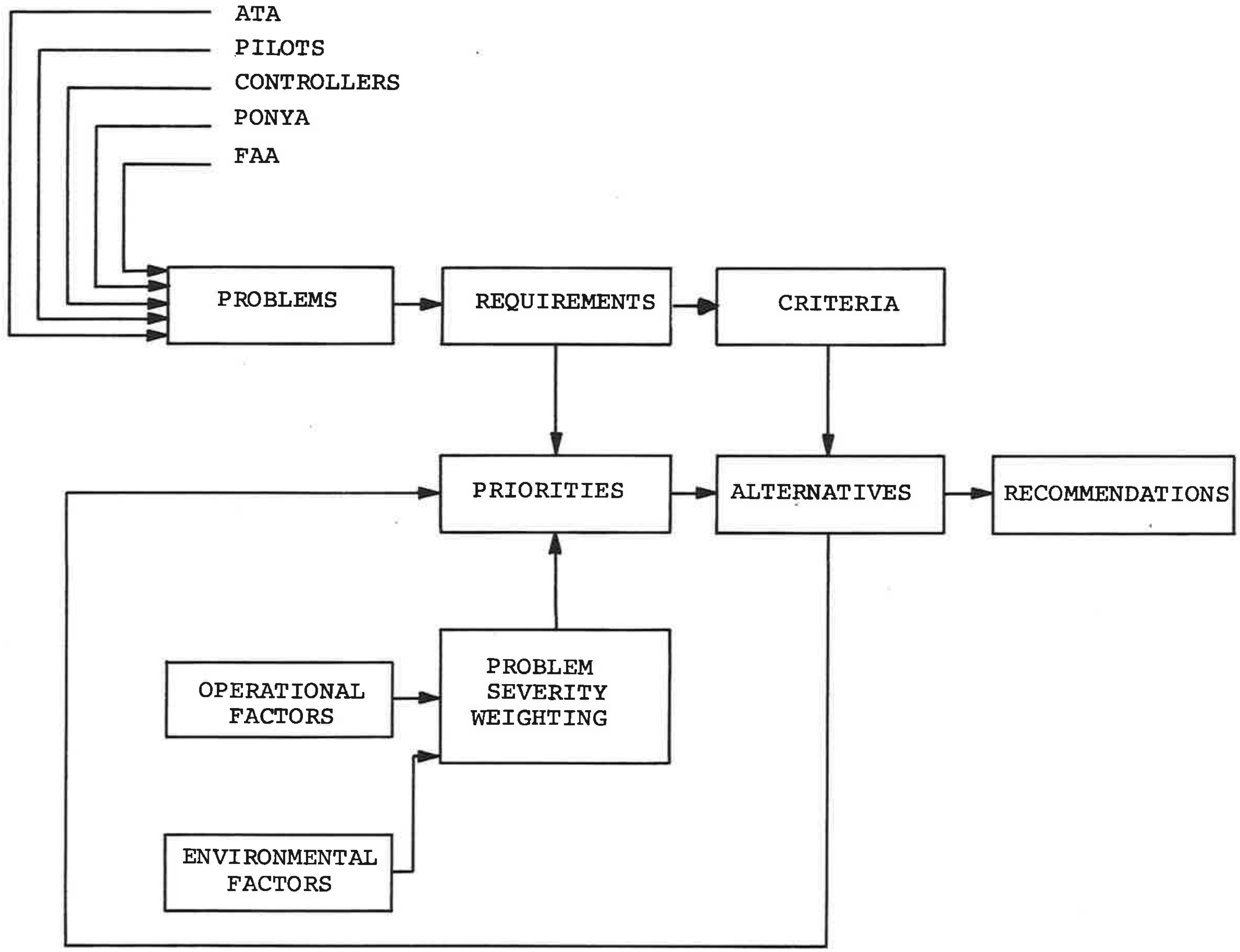

Figure 1. Iterating a Solution

was also influenced by pilot and controller interviews as well as from observations of tower operations. The following criteria were considered in evaluating alternative systems for use at Kennedy:

Controller workload

Pilot workload

Reduction of communications congestion

Reduction of stops and delays

Operation in adverse weather

Reliability

Redundancy

Installation costs

Availability (lead time)

ALTERNATIVES

The following were considered as alternative systems for use at Kennedy. It should be noted that some alternatives were meant only as interim solutions.

1. Improved bright display with retrofitted ASDE II
2. New radar with bright display
3. New tower with new radar
4. New tower with multiple radars
5. Old tower with multiple radars
6. Fully automated STRACS with discrete sensors
7. Fully automated control with digital radar
8. Austere Mode STRACS (Intersection Control)

EVALUATION OF ALTERNATIVES

1. Improved ASDE Bright Display and Upgraded ASDE II Radar

As an interim solution, an improvement to the present ASDE II bright display and upgrading the existing ASDE II radar are suggested by replacing the vidicon scan converter with a high resolution bright display and providing a retrofitted ASDE beyond that planned in the current FAA program. Justification for this change is an unsatisfactory performance of the present ASDE II bright display, particularly in reference to the quality of the uniformity of the picture and resolution. Although ASDE II scan rate will remain at 60 RPM, an improved bright display will provide satisfactory performance to the user suited for a prolonged and continuous operation.

2. New Radar with Bright Display

The expected significant changes resulting from this effort are 1) improved radar reliability and maintenance, 2) decrease in radar size and weight, 3) improved precipitation characteristics and 4) the addition of continuous tracking information on the analog display reducing any appearance of "aircraft mapping". To achieve a continuous tracking, higher antenna scan rate is anticipated. The best radar available today for the airport surveillance application should be used with limited design modifications. This radar is expected to have a satisfactory performance and also should be acceptable to the user and should become a basic building block to achieve a full airport coverage using a multiple radar approach.

3. New Tower with New Radar

I. Sight Line Considerations

Sight line calculations have been made for potential tower heights of 250, 275 and 300 feet with object resolutions of 4, 6 and 7 feet at the edge of the inner taxiway. All calculations have been made with reference to PONYA drawing #KIA8855, dated 3/18/68 and entitled "CTA Height Restrictions Based on Raised Control Tower in Existing Location (273'MSL)". This drawing notes proposed contour lines for allowable building heights for object resolutions of 7 feet, the existing lease lines, and proposed lease lines.

For the calculations it was assumed that any airline may build at its discretion, subject to PONYA/FAA approval, a 30 ft. building on the 42 ft. MSL line. The apron is referenced at 12 MSL. Only Pan American so far has exercised this option but if a new tower were built other airlines could exercise this option. Therefore, our calculations assume all airlines may exercise this option.

In the calculations that are detailed in Appendix E are shown the shadowed distances for each of the airlines and how far these shadows overlap the taxiway. Also shown for the overlap regions are the amount of movement of the 42 MSL line toward the tower required to eliminate this overlap.

For a tower height of 250 ft., a number of blind spots occur for object resolutions of 4 ft., 6 ft., and 7 ft. at the inner taxiway. At a tower height of 275 ft., only two blind spots would occur for a resolution of 4 ft. At 300 ft., no blind spots would be present for all object resolutions.

II. Weather Considerations

No direct data exists for hours per year that a 145 ft. tower, the present JFK tower height, or other tower heights of 250, 275, or 300 ft. would be above the clouds. Therefore, a linear extrapolation of existing data[2] was done (see Appendix E for calaulations) yielding the following data.

Tower Height (ft.)	Total Hours Per Year in Clouds	Hours Per Year in Clouds More Than Present Tower
300	221	129
275	198	106
250	175	83
145	92	0

4. Near Tower with Multiple Radars

The same considerations apply here as in alternative 3 above, except that blind spots and shadowing are materially eliminated.

5. Old Tower with Multiple Radars

The multiple radars would eliminate blind spots due to buildings and reduce the effects of the shadowing of small aircraft by large aircraft when the aircraft are close together and when surveillance accuracy is required.

[2]JFK Climatological Summaries

6. <u>Fully Automated STRACS with Discrete-based Sensors</u>

The choice of a fully automated STRACS system operating from information supplied by discrete-based sensors was predicated upon the availability of all system components. Although this type of system can be implemented and made operational within a reasonable period of time, the present system as outlined by PONYA/LFE has a number of limitations:

- .man/machine interface inadequate
  - .back-up mode
  - .data entry
- .no operational procedures for local/ground controller interface
- .detection loops and guidance lights reliability
- .high cost

For details, see Appendix B.

7. <u>Fully Automated Control with Digitized Radar</u>

The choice of a fully automated control system operating from information supplied by several digitized radars is based upon the fact that radar information is continuous. However, since the radar component supplying the input information to the system is not available, a R&D effort is being initiated this year by TSC to establish the feasibility of generating the required accuracy and ability to discriminate between aircraft and to eliminate background clutter.

8. <u>Intersection Control</u>

Autonomous intersection control has been considered as a possible short-term solution to the problem of controller workload. The system would include signal heads located at all entrances to an intersection and actuated by the ground controller or local control switching logic. This idea appears attractive as a means of assigning right of way to conflicting traffic at certain intersections within the controller's blind areas.

Limited analysis of controller tapes at JFK international airport indicate limited applicability of an autonomous local intersection controller. Secondly, a local intersection controller is not a proven concept, and therefore it is recommended that it first be tested at a less busy airport than JFK as per the AGTC development plan. These views have been corroborated in visits with JFK tower personnel.

The French government has concluded that an autonomous intersection controller is a viable solution and is proceeding to design and test one at the Paris Orly Airport.

IV. DEVELOPMENT APPROACH

APPROACH

The approach taken for generating a detailed recommendation on what to do about the Kennedy AGTC problem is to recommend an immediate needs improvement (one and one-half year), to recommend a near term improvement (three-four years) and finally, a recommendation for a long term solution (five years). This has been done because it has been determined that: (1) there is a need at the present time for a good system in bad weather; (2) there will be need for a good system to alleviate the blind spot problem in three to four years, and (3) there will be a need for an automated control system in five to eight years due to increasing operations in bad weather and saturated control conditions in VFR weather. The recommended plan consists of four recommendations, as noted below.

JFK RECOMMENDATIONS

IMMEDIATE NEEDS

1) Develop and install an improved bright display and upgrade the existing ASDE II radar

There exists a definite need to augment controller visibility. This need could be met by the development and installation of a no-clutter, high resolution, electronic plan view display and aided by upgrading the existing ASDE II radar to improve its background clutter rejection and signal-to-noise ratio. Such a system would enable the ground controller to assess quickly and accurately the current traffic situation without relying on inadequate visual sightings. This is a task (Phase 1A) that has already been identified as a required one in the Airport Ground Traffic Control (AGTC) Development Plan. This recommendation consists of the current FAA Oklahoma City ASDE retrofit with a follow on retrofit package and a bright display to replace the current Bright II as referenced with AGTC Development Plan.

2) Improved Guidance

Because of several guidance problems, i.e., a) ill defined taxiways and intersections, b) lack of clear and readable signing and c) pilot retention of assigned routing, it is suggested that an improved guidance subsystem be installed at Kennedy; for example, the installation of additional center-line lights at critical taxiways and runways, the installation of reflective signs and the publication of runway to airline terminal routes for all pilots (a procedure manual).

NEAR TERM IMPROVEMENT

1) Develop and install a new radar and bright display

Since, at JFK, there is a need at the present time for a good system in bad weather to tell that an aircraft is clear of the runway and clear of the taxiway, it is recommended that a new basic single surveillance radar system with an enhanced display having the option of video processing to provide background or map supervision be developed and installed at JFK. This recommendation will make use of Tasks IB.2 and IB.3 of the AGTC Development Plan (Basic Radar and Display Evaluation and Background Suppression Evaluation).

2) Develop and install a multiple radar system with an integrated bright display

In approximately three years time, blind spots will be a more severe cause of surveillance problems than bad weather because of additional PONYA construction at the airport site. In order to provide adequate surveillance information to the controller, a multiple radar system with an integrated bright display is recommended. In this way, shadowing of certain critical areas and blind spots caused by line of sight obstructions, such as building and large aircraft, will be alleviated (reference Task II.0, Multiple Radar Evaluation in AGTC Development Plan).

LONG TERM

1) Development and installation of an automatic control system

In five to six years time, it is anticipated that an automatic ground traffic system will be needed for JFK. At this point in time, it is not clear whether weather (IFR operations) or saturated control during VFR conditions will dictate its need. It is recommended that a discrete sensor based automatic control system, or a radar based automatic control system, be developed and installed for JFK (reference Tasks IV.1, Radar Based Automatic Control System Evaluation, and Phase 3.0, Discrete Sensor Based Automatic Control System, of the AGTC Development Plan).

SUMMARY

The recommendations for JFK are summarized below and the schedule times are compatible with the AGTC Development Plan Schedules.

Problem	Suggested Solution	Time	Cost
Poor bright display Resolution & contrast	Improved bright display and ASDE II retrofit	15 mos.	$70K
Ill defined taxiways & runways	Improved guidance signal lights & signs	12 mos.	$1M
Weather	New radar and bright display - installed	31 mos.	$300K
Blind spots	Multiple radars with integrated bright display	43 mos.	$1.5M
Control	Automatic control system	62 mos.	$7M

TASK DESCRIPTIONS

Based upon the approach cited in the previous section, a recommended plan for JFK has been laid out. The task flow chart is shown in Figure 2. These tasks assume the availability of a number of inputs from the AGTC program plan effort as shown in this figure. After implementation and installation of each improvement at JFK, onsite test and evaluation will occur prior to formal acceptance and implementation of the next phase. The task flow represents a five phased effort aimed at 1) immediate needs improvement to provide an improved

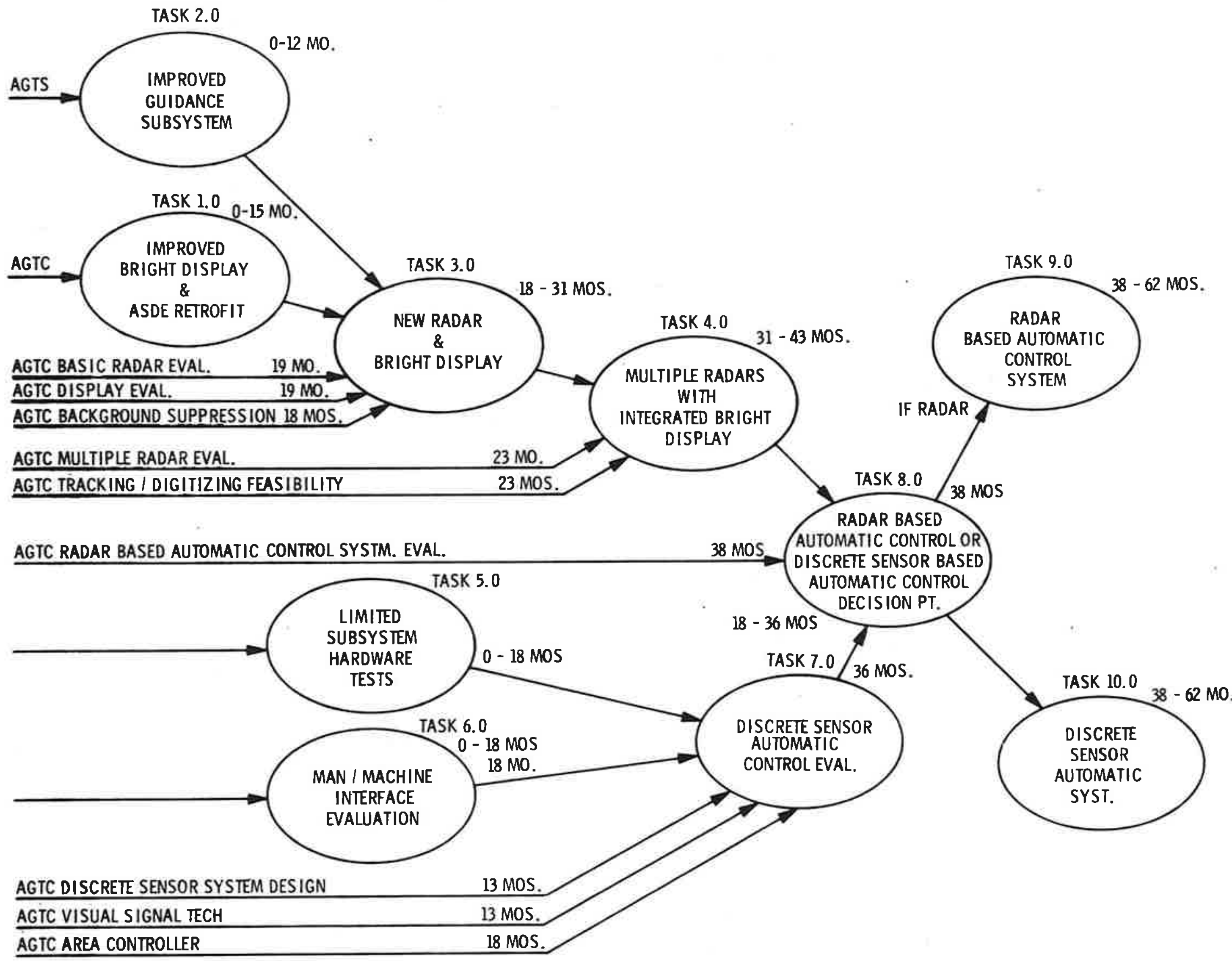

Figure 2. Task Flow

ASDE II/Bright Display System for improved pilot guidance, 2) immediate needs improvement to provide an improved guidance system and better display resolution and contrast, 3) a new radar to alleviate the surveillance problem (aircraft position and identification) in bad weather, 4) a multiple radar system with integrated bright display for alleviation of blind spots, and 5) the installation of an automatic ground control system due to increasing operations in bad weather or saturated control conditions in VFR weather.

TASK 1.0. Improve Bright Display and Upgrade the Existing ASDE II Radar

The objectives of this task are to display details of the JFK airport with sufficient distinction so that it can supplement or replace the visual observation of a control tower operator. An exception is the shadowing effects from the high-rise structures. The approach is to improve the present ASDE II radar by improving performance of the present bright display, sensitivity of the receiver and rain clutter, and background noise rejection and then to incorporate these changes as a Modification Kit into the presently operating ASDE II radar at JFK using a ASDE II Radar STANDBY CHANNEL.

Required inputs from the AGTC Development Program Plan for the successful completion of this task are:

1) An improved bright display. Candidates are (i) a direct view display storage tube similar to the Hughes storage tube (ii) an improved scan converter bright display system similar to DECCA's and (iii) a double ended storage tube similar to the Thomson CSF system at ORLY, PARIS. The best of these candidates could be evaluated through a lease arrangement in the very near future with no serious disruption of tower operations.

2) An ASDE II Modification Kit. The following improvements may be possible: a) a new solid state receiver to reduce rain clutter and background scattering, b) an improved RF Amplifier (solid state pump if applicable), c) balanced Mixer (Schottky) and d) a solid state duplexer (ferrite with limiter).

It is recommended that JFK be considered as the system test and evaluation test site for this task in order to expedite completion of task.

TASK 2.0. Improved Guidance Signal Lights

This task addresses the problem of a) ill defined taxiways and intersections b),lack of clear and readable signs on the airport surface, and c) pilot retention of assigned routing. The following improvements are suggested:

1) Install additional centerline lights at critical taxiways and runways.

2) Install reflective signs at major inner/outer taxiway and runway intersections.

3) Route designations on the signs as well as taxiway label (e.g. Orly's ingoing sign design program)

4) Provide all pilots with a map of runway to airline terminal routes

5) Initiate new maintenance and inspection procedures to reduce the number of guidance light failures.

6) Require all new plows to use rubber-tipped snow plows to reduce damage caused by snow-plowing.

Task 3.0 New Radar and Bright Display

The objective of this task is to install and test a new radar with a bright display and after a test and evaluation phase, to commission the radar for operational use. This task makes use of Tasks IB.2 and IB.3 of the AGTC Development Plan (Basic Radar and Display Evaluation and Background Suppression Evaluation). The technical approach of these tasks is to evaluate the Decca, TI, and other radars and from the evaluation data, design and requirements review and available state-of-the art developments define a new radar specification; to then procure and evaluate a new radar meeting this specification.

Task 4.0 Multiple Radars with Integrated Bright Display

This task addresses the installation, test and commissioning of a multiple radar airport ground control system for operational use. This task requires as inputs the results of Task II.0 (Multiple Radar Evaluation in the AGTC Development Plan). The objective is to provide satisfactory AGTC system operation, by using Multiple Radars to display all runways and taxiways of JFK so that they are clearly defined and all objects in these areas are plainly visible in all weather and with ambient lighting conditions.

The recommended approach is the installation of three New Radars with a microwave data link and a single display. One of these radars may be the radar installed for the completion of Task 3.0.

Task 5.0 Limited Subsystem Hardware Tests*

Because at the present time there exists some question concerning the reliability of the guidance and control lights and the detection loops for the proposed STRACS system as it presently exists, it is recommended that limited hardware tests be undertaken. The guidance lights are subject to failure due to snow and sand and the concrete pavement in which the detection loops are installed has been found to move. The effect of this movement on the detector loops is not known.

The technical approach is to conduct live performance tests of the following basic system components:

1) Inductive loop detectors

2) Center-line lighting

3) Local controllers

These tests should be conducted over a period of one year. During this time interval, the equipment will be exposed to all possible environmental conditions peculiar to JFK. The performance of each component will be under surveillance at all times, and will be checked for:

1) reliability

2) base of maintenance

3) output response

4) failure rate

5) false alarm rates

6) maintainability

*This task will not be required if the local area controller as detailed in the AGTC development plan is tested at an airport whose environment is similar to that of JFK.

Since failure rate is a function of environmental conditions, JFK should be chosen for the test site. First hand failure reporting and analysis will facilitate product improvement and corrective action follow-up.

The end result of these tests will be a demonstration that the aforementioned equipment will perform its function under given environmental conditions for a specified length of time and, if not, will provide sufficient data for corrective action.

The suggested tests on the three basic components are delineated below. The inductive loop performance will be checked against another reliable intrusion alarm device to seek out the existence of false alarms or malfunctions while responding to normal aircraft traffic. The outputs will be monitored and recorded on a tape recorder. The output wave form will be checked for adherence to specifications.

The centerline lighting will be mechanically cycled through several levels of intensity as well as switched on and off. The light output will be masked so tests will not interfere with normal traffic flow. The lights will be installed at taxiway nodes and runways where they will be subject to impact landing, braking action, and drag forces of aircraft bogies and subject to pavement construction faults. Temperature sensitive devices will determine the state of each light.

If, as part of these limited subsystem hardware tests, a local controller is installed in the field, it may be used for environmental testing. Therefore, it can supply test signals to the centerline lights while diagnostic checks are made on unused logic components.

<u>Task 6.0 Man/Machine Interface Evaluation*</u>

The objective of this task is to perform an operational analysis of the impact of STRACS on the JFK tower operations and to recommend an improved man/machine interface for automatic ground control systems. The present STRACS man/machine interface is inadequate because of a poor backup mode and poor data entry capabilities. No controller procedures for the local/ground controller interface have been developed. The controller's only

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*This task, as of the present time, has not been identified in the AGTC development plan as a required one.

data entry device is a keyboard, and thus, data entries of identification and destination for each aircraft under his command will be extremely time consuming.

The recommended technical approach is to perform man/machine interface evaluation via a real time simulation at DOT/TSC or at NAFEC.

Task 7.0 Discrete Sensor Automatic Control Evaluation*

This task addresses the evaluation of a discrete sensor based automatic control system at a medium sized airport. Based upon the system design developed in task 3.4 of the AGTC Development Plan, the automatic control system will be fabricated and field tested under live traffic and live controllers at a medium sized airport. Cost estimate for a medium sized airport such as Logan is $3M.

During the field tests, it is recommended that JFK controllers come and critique the system so that any deficiencies left in the system may be corrected.

Task 8.0 Radar Based Automatic Control or Discrete Sensor Based Automatic Control Decision Point

Based on the results of Task 7.0 and Phase IV of the AGTC Development Plan, the Radar Based Automatic Control System Evaluation, a decision will be made as to which of the automated control systems will be implemented at JFK.

Tasks 9 and 10 Radar or Discrete Sensor Automatic Control System Implementation

This task addresses the fabrication, installation, and implementation of an automatic control system at JFK based on the designs developed in the previous tasks. Task 8 will determine which type of automatic system it should be.

RESOURCES

See Tables II, III, and IV.

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*This task is included as part of the AGTC Development Plan.

MILESTONE/SCHEDULES

The JFK development program schedule is shown in Figure 3. The following is a list of program milestones.

Task 1.0	Improved Bright Display with ASDE Retrofit	15 mos.
Task 2.0	Improved Guidance Subsystem	12 mos.
Task 3.0	New Radar and Bright Display	31 mos.
Task 4.0	Multiple Radars with Integrated Bright Display	43 mos.
Task 5.0	Limited Subsystem Hardware Tests Completed	18 mos.
Task 6.0	Man/Machine Interface Evaluation	18 mos.
Task 7.0	Discrete Sensor Automatic Control System Evaluation	36 mos.
Task 8.0	Automation Control System Decision Point	38 mos.
Tasks 9.0 and 10.0	Automatic Control System Implementation	62 mos.

TABLE II

COSTS PER TASK

	MY	CONTRACT	TIME (Mos.)
Task 1.0	1.0	$ 90K	15
Task 2.0	1.0	$1M	12
Task 3.0	1.0	300K	31
Task 4.0	2.0	1500K	43
Task 5.0	1.0**	100K	10
Task 6.0	10.0*	300K*	18
Task 7.0	4.0	3000K***	36
Task 8.0	1.0	-	38
Tasks 9.0/10.0	8.0	7000K	62

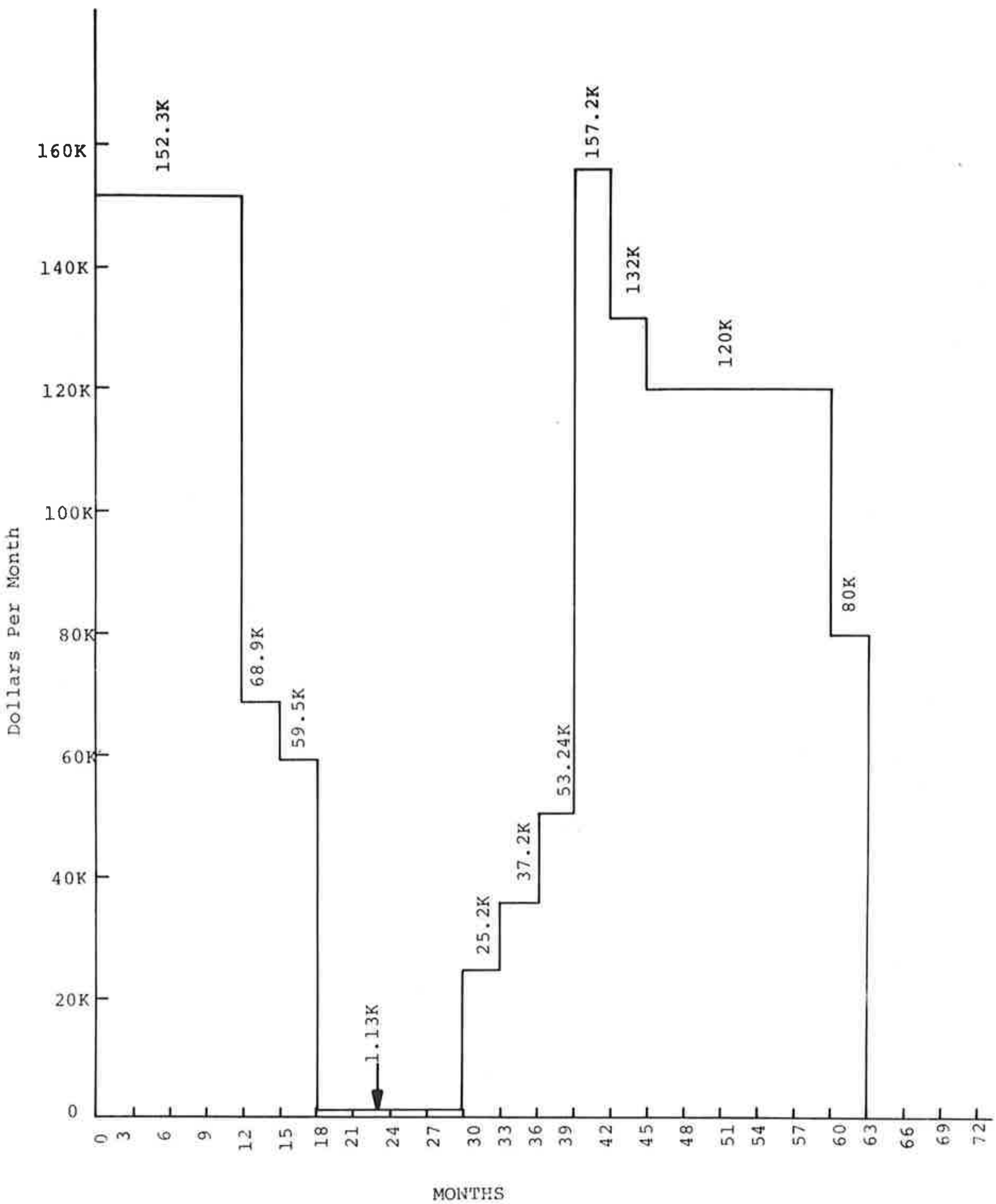
* New requirement for AGTC Development Plan

** May be part of AGTC Development Plan depending on site selection for Local Intersection Controller

*** This is included in AGTC Development Plan

TABLE III

JFK Schedule Cost Plan



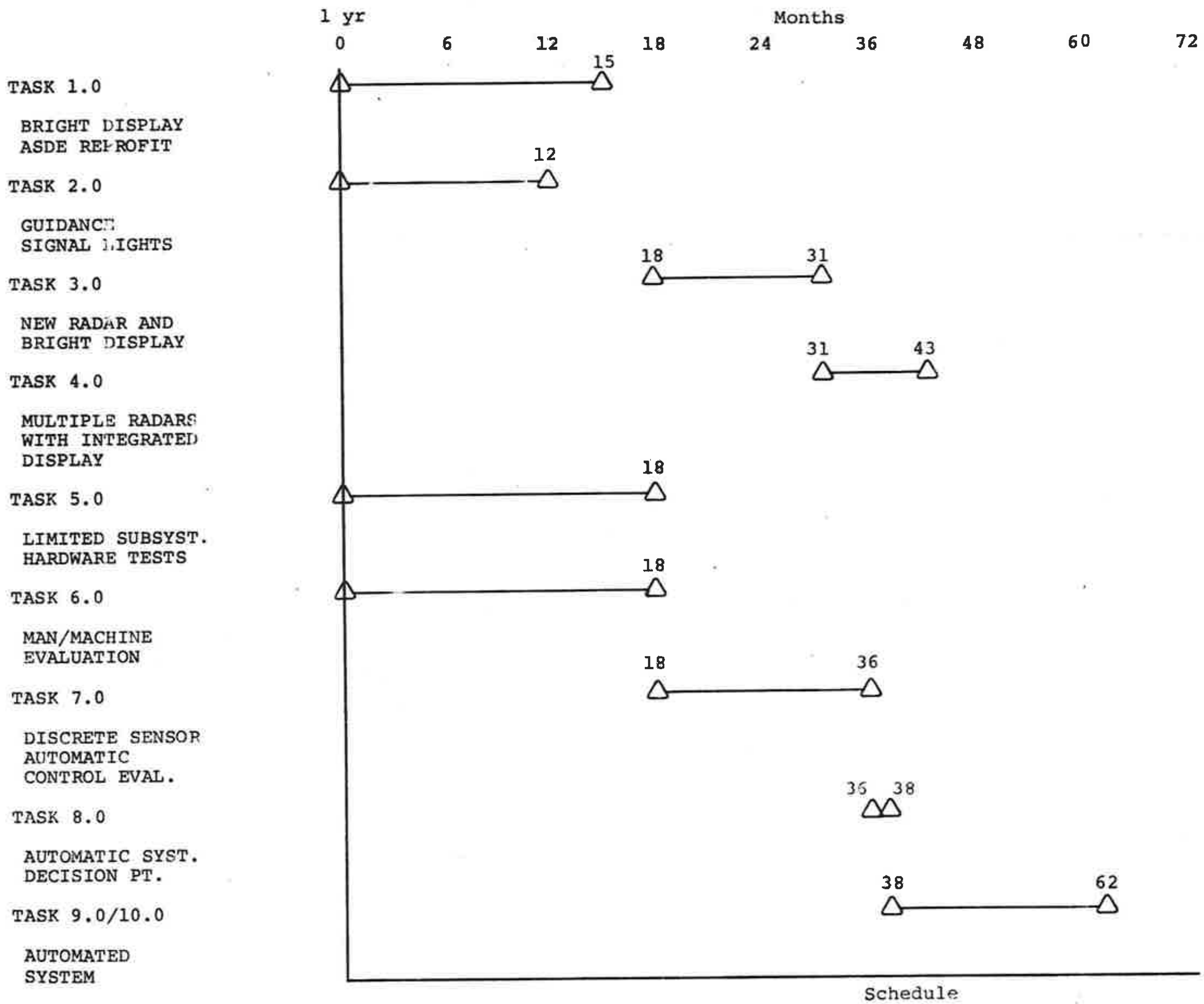


Figure 3. Schedule

APPENDIX A

JFKIA PROBLEM AREAS

INTRODUCTION

The problem areas noted below have been identified by review of the LFE monthly progress reports, personal discussions with the ATA, FAA Eastern Region, PONYA, JFK Tower and personal observations of the JFK Tower operations. The following visits and discussions took place:

FAA Eastern Region - J. Ritz	October 4
JFK Tower - M. Sarli, Assistant Chief	September 28
STRACS Steering Committee	September 23
AGTC Working Group	September 22
JFK Tower Visit	September 9
PONYA	August 31
ATA Eastern Region	August 30
FAA Eastern Region	August 30
JFK Tower Visit	August 30
JFK Tower - W. Parenteau	August 18
JFK Tower Visit	August 2

PROBLEM AREAS

1) If centerline lights are being used for guidance, they should also be used for longitudinal and routing control.

2) The current taxiway signs at JFK are confusing due to taxiway intersections at odd angles.

3) As long as the edges of the taxiway are cleared of snow, the captain did not feel any lit edge markers were necessary when the pilot guides the A/C via the centerline lights.

4) The yellow, center of node, omnidirectional centerline fixture is a good idea. Since each plane is turned differently with regard to the node center, this is a good point for guidance. Blinking this light for an emergency seemed to be an acceptable procedure.

5) The green "Go" bar is not necessary to reinforce the turning off of the red bar.

6) The B-747 inertial system readout showed that the captain travels at about 5 knots in poor visibility. He feels that the speed is slow enough not to need more than a hundred plus feet of warning of a turn.

7) Taxi speed must remain under the control of the pilot.

8) Visual signs should display the standard red/amber/green colors. Centerline lights for guidance are preferred. Taxiway edge lights or reflectors should be retained for better definition of taxiway areas and intersections.

9) STRACS should improve the current excessive exposure to ground vehicles while taxiing.

10) Blue edge lights cause congestion problems even from the cockpit of a DC-9 (sea of blue).

11) Centerline rather than sideline control recommended by a ratio of 5-1. However, it is felt present centerline fixtures are old fashioned.

12) Pilots would not taxi faster than 15-20 knots under any conditions.

13) Turns at 8-10 knots standard for any aircraft due to safety and/or aircraft characteristics.

14) Preferred spacing between aircraft is 1000'.

15) Taxiway exits from the landing runway should be visible from a long distance and should indicate where the pilot should exit (but not must exit).

16) Taxiway edge markers on turns are very important in taxiing a B-747.

17) There is no advantage in speeding on the taxiways to arrive at a queue.

18) Delays should be taken in the enroute queue rather than inactive staging away from the gate. Aircraft carry an hour's extra fuel for pre-takeoff queueing.

19) The height of the pilot in the B-747 causes him to lose forward depth of field. The pilot does not know the extent of his slow-down without having to look out the side.

20) Current signs at Kennedy are placed such that it is impossible to discriminate between which of two adjacent taxiways the sign refers.

21) Some pilots don't retain or can't recall or recognize their assigned routing sequence and must be guided to their gates.

22) There exists multiple blind spots where the ground traffic controller in the tower cannot directly observe or track the movement of aircraft.

23) At long distances from the tower, especially beyond the outer perimeter, the shallow sight angles result in ambiguities in the estimate of aircraft position.

24) At night, even during periods of good visibility, the presence of lights in and around terminals and other buildings generates an excessive amount of glare and light clutter against which background the tracking of aircraft motion becomes exceedingly difficult.

25) The main problem with low visibility, beyond difficulties in visual tracking, is in ascertaining the passage of aircraft through intersections before clearance to conflicting traffic can be given.

26) The advent of large size aircraft, such as the 747, has created severe clearance problems. As these large aircraft tend to obstruct adjacent taxiways and intersections, it has become necessary to hold clearances on certain adjacent links and intersections until the large aircraft have passed. This has often resulted in rerouting of aircraft over longer distances and/or additional stops enroute to gates or staging areas.

27) Link closures for maintenance or construction are a continuing problem at KIA. While major efforts are made to re-open them for the evening peak, they may be considered to be random in both time and place.

28) Insufficient staging areas.

29) Controllers want directional cues on display.

30) Some A/C arrive at take-off Q ahead of other A/C who have received prior clearance.

31) Insufficient identification of taxiways and intersections.

32) Excessive radio chatter for effective communication while pilot is taxiing.

33) Centerline lights on taxiways shielded by snow and/or sand during part of the year.

34) Present rate of failure of centerline lights is too high.

35) Pilots desire traffic information while taxiing.

36) Pilots want signs visible at 1000' (signs not visible).

37) While taxiing, pilots run down a checklist and consider taxiing only a peripheral task. When they do look up they tend to see only straight ahead.

38) Runway crossing.

39) Excessive volume of voice communications.

40) Location, identity, and direction of motion.

41) Emergency procedures.

42) Maintenance problems with centerline lights.

43) Outbound entering active taxi area from ramp on/off same time.

44) No lights around turns, deficiency in centerline lights.

45) Unscheduled A/C no departure fixes.

46) No gate for arrivals.

47) Pilot frequently makes wrong turn due to unfamiliarity with airport.

BLIND SPOTS

Please refer to Figures A-1 and A-2 for the majority of the blind spots as of 1966 and the present time per conversation with Mike Sarli, Assistant Chief, JFK Tower and PONYA drawing number, JFK-8872, dated 4/13/68.

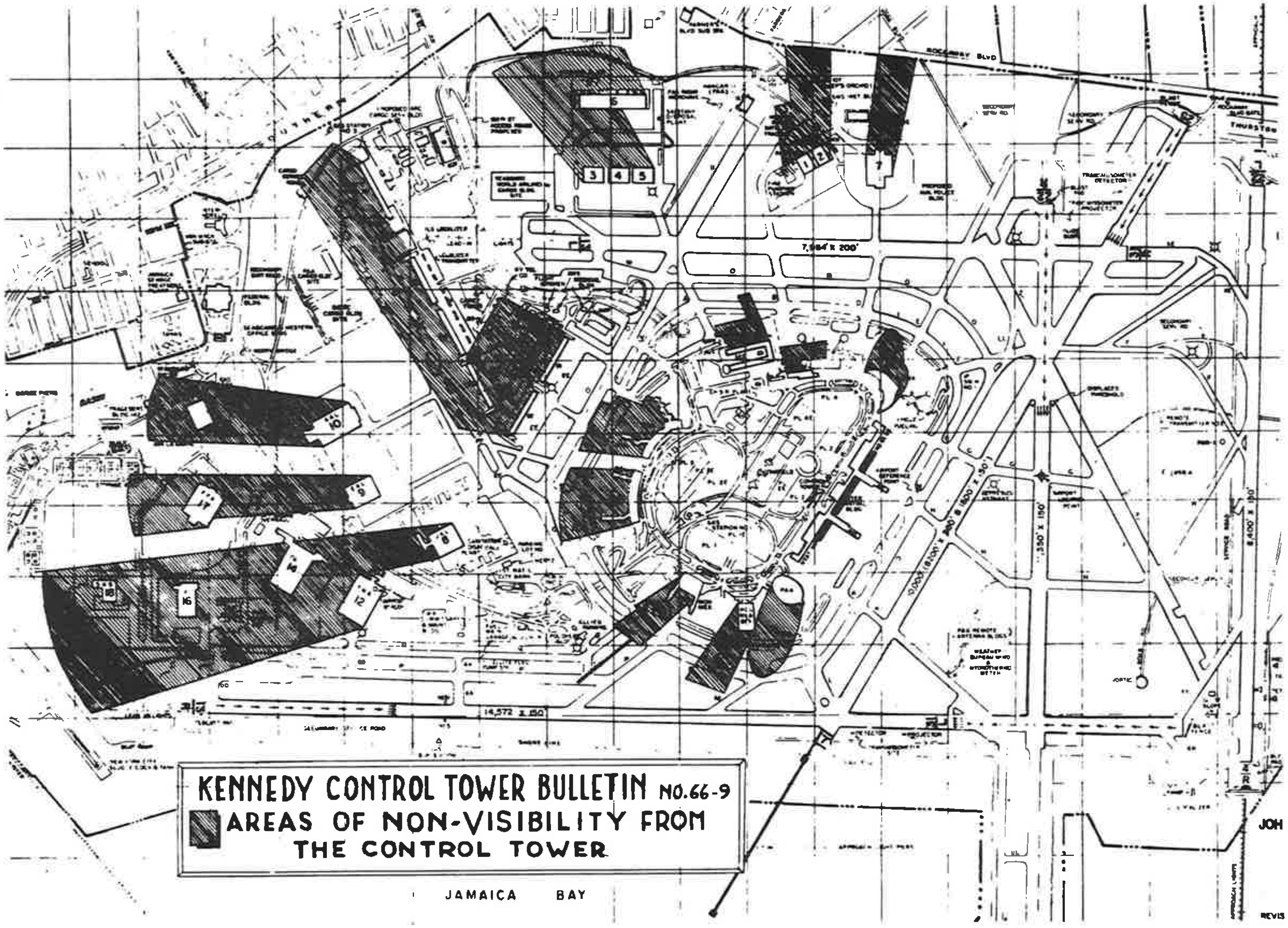


Figure A-1. JFK Areas of Non-Visibility From Control Tower (Present)

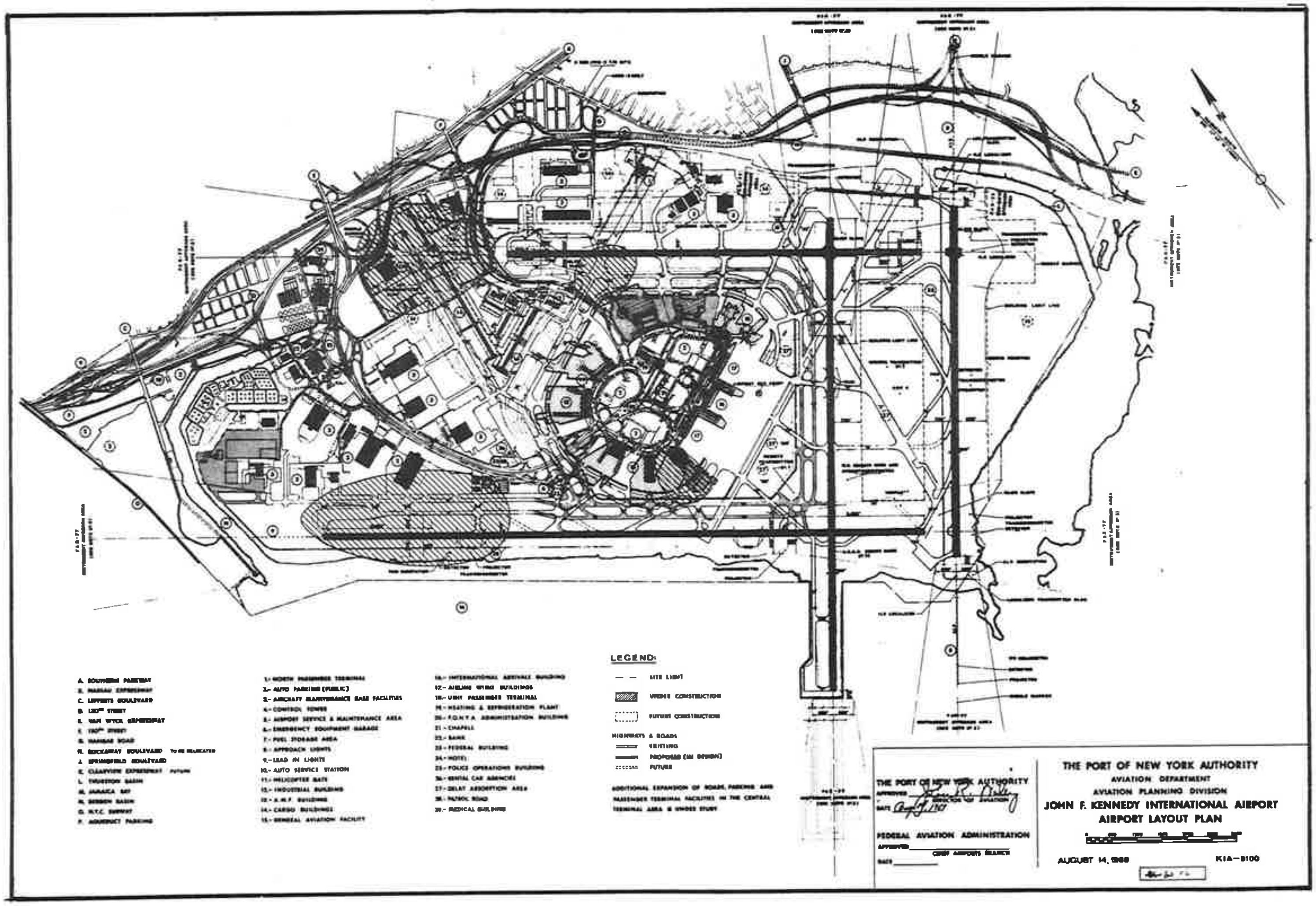


Figure A-2. Areas of Non-Visibility From JFK Control Tower (1966)

APPENDIX B
STRACS

INTRODUCTION

The PORT of New York Authority has embarked upon an ambitious program to develop for KIA a non-cooperative surface traffic control system called STRACS. STRACS is intended to be a semi-automatic system for the guidance and control of taxiing aircraft and emergency fire/rescue vehicles on the taxiways. It is believed that this will be a solution to a number of problems developing at KIA. These are:

1) loss of direct line of sight between the control tower and major taxiways

2) lack of sufficient clearance between the inner and outer taxiways and connecting links for present-day large aircraft

3) increased volume of controller-pilot voice communications

4) increased airport traffic

5) increased tower-taxiway range

It was the intent that STRACS be designed for the purpose of reducing the workload of the ground controller by allowing him to monitor a fully or partially automated system and effectively increase the capacity of the taxiways by allowing maximum taxiway utilization. The system is to improve safety and reliability of operation under continually lower visibilities, and to minimize the volume of pilot-controller voice communications.

STRACS, as a partially automated system, is feasible and within the state-of-the-art for the discrete sensor based system. The STRACS concept can be applied as:

1) a total system

2) a preliminary system to a more centralized system

3) a back-up to a more centralized cooperative system

4) a hybrid of radar and discrete sensors

The STRACS system currently under study does route aircraft between a point of origin and a destination with reduced volume of voice communication. It certainly permits routing at lower visibilities and in blind areas of the taxiways. The system has high reliability by virtue of its dependence on many presence detectors. A catastrophic failure or degraded performance of one detector does not disable the entire area-wide system. A fail-safe mode can be instituted which essentially returns control to the pilot at the node in question. The STRACS system, with its priority logic, does expedite the routing of aircraft off the runways and onto the taxiways, and attempts to keep traffic flowing on the inner and outer taxiways. Priority logic is established for the "normal" and "austere" modes. Visual signaling at nodes increases the ambient illumination level and, in turn, the scene contrast. Signaling pilots by RF means does not offer this advantage. Visual signaling, however, does suffer from backscatter effects, requiring some control over light intensity. The ground controller is given a display with information on the direction of traffic at the nodes, the count of aircraft between nodes on the inner and outer taxiways and the identification of each aircraft associated with the count. The display shows the geometric arrangement of the taxiways and the runways, the runway combination being used and the mode of control.

The entrance of aircraft into the STRACS system is controlled by the local controller at the runway turn-off links, and by the ground controller at the apron. Exit from the system is controlled by these same controllers.

If any destination is unavailable to an aircraft, it is the ground controller who manually intervenes to choose staging areas and who determines order of admission and removal from these areas. For traffic control purposes, the apron may be considered an entrance staging area. Thus, the function of STRACS is to replace traffic control with an entrance control function.

The underlying cause for the establishment of a ground control system at KIA was the delivery of 747 aircraft to the airlines. The size of this aircraft resulted in a need for enlarged aprons and new building construction. As a result of these changes, other problems developed. The size of the 747 created a control requirement that no aircraft be allowed to stop in many taxiway links without tying up the entire routing system. Also, a surveillance problem occurred because the construction of new buildings created blind spots for the control tower and because the 747 shadowed other aircraft whenever the 747 came in between other aircraft and the control tower.

With the advent of larger and faster aircraft in the future, it becomes obvious that there will be an increased need for higher airport traffic capacity and more efficient ground-traffic routing made possible by a control system such as STRACS.

STATUS

Summary

The complete STRACS design at the present time is incomplete. No computer hardware specifications or software specifications are available. In addition, the power system design is incomplete.

Insufficient simulation runs have been generated. Only the preliminary simulation results of run #1 are available. Run #1 consists of simulating the operation of 80 A/C per hour using 31L for takeoffs and 31R for landings.

No staging plans have been generated and insufficient field test plans[1] have been developed. Also, only a crude cost analysis for the implementation of STRACS at JFK has been made. This cost estimate was approximately $7M.

The expected design completion date is 1 February 1972.

STATUS BY TASK

Task 1 - Data Collection

This task was a collection of data from pilots, FAA, operations, maintenance, planning and fire/rescue personnel regarding procedures which pilots use and their response to guidance.

The major items are:

1) the aircraft speed on the straight taxiway and at turns by aircraft type

2) the aircraft spacing on the taxiway based on the aircraft types being spaced

3) the pilot's opinion of currently existing lights and signs

4) the airline's procedures regarding apron traffic control

Task 2 - Candidate Logic Evaluation

This task involved discussions with controllers regarding routing procedures and intersection traffic control priorities. Reviewing the reports, it appears LFE would meet with the controllers at regular intervals to discuss routing maps and intersection control logic. The problem that appears to exist is that no formal logic existed before this study and it has been difficult to reduce

[1] Appendix G, June 1971, STRACS Report, STRACS Monthly Progress Report #15, August 1971, STRACS Test Demonstration Summary to FAA/PONYA, 6/28/71.

controller procedure to computer logic. We believe the simulator can be used to generate situations for controller comment to provide LFE with further insight to assist in improving the logic. However, the logic, as specified, meets the requirement that no aircraft will be forced to stop in a short link.

Task 3 - Guidance and Control Hardware

The guidance and control hardware is the standard FAA inpavement semi-flush centerline lighting with red or green filters. A redesign is in progress to correct the problems associated with these lights due to snow plow and hammer damage.

Task 4 - Remote Controller Hardware

The intersection and austere logic are specified, but to date, no controller has been built. The austere mode is complete except for intersection 5.

Task 5 - Detector Hardware

In June 1971, LFE reported detector tests which indicate the loops will adequately perform the detection job. MTBF for the most probable loop detector configuration has been determined to be 74,400 hrs.

Task 6 - Communications Hardware

LFE, in the June 1971 report, gives a report on their STRACS line shared communications system, giving costs developed from an industry survey.

Task 7 - Power Supply Hardware

Based on the cabling constraints set up by LFE and PONYA and the requirement that power will be delivered by a cable bank between the inner and outer carrousel as set in Attachment 1, the installed cable costs are approximately $5M. As of July 1971, the final power supply requirements were not set.

Tasks 8 and 9 - Tower Display Design and Mockup

LFE has prepared a tower display mockup. The display, while possibly adequate for normal operations, is not adequate for austere or manual operations, and has poor data entry capabilities. The major task is for LFE to continue to work with the controllers to come to an agreement on the best type of display meeting the controllers needs and the allowable space. Also, it is felt that, as a minimum, the computer should produce flight strips for manual control.

Task 10 - Staging Plan

There was no work on this.

Task 11 - Field Test

A valid test of STRACS involves a substantial part of the actual implementation and, hence, is impractical. LFE has submitted field test plans as in Appendix G of the June 1971 report, for a field test on part of the airport. Such a test is only a hardware shakedown, but cannot verify logic or interact properly with the controller.

Task 12 - Final Report

Not written.

Task 13 - Program Management

Task 14 - PONYA Meeting

Task 15 - Subcontractor Liaison

Task 16 - Software Subcontractor

The simulator part of this contract is only partially complete. CSC has programmed the simulator and has made two runs for LFE. However, the simulator has not been validated. The simulator could be run to establish that it produces reasonable results and then used to check routing logic.

The software specifications have not been written as of the September 1971 report.

LIMITATIONS

Summary

- man/machine interface inadequate
  - backup mode
  - data entry
- no operational procedures for local/ground controller interface
- detection loops and guidance lights reliability
- inactive runway staging limitations, a standard JFK procedure

.staging area

.high cost ($8.4M for JFK)

DISCUSSION

Man/machine interface is inadequate because of a poor backup mode and poor data entry capabilities. If a failure occurs during normal operations when the ground controller is monitoring the display it is not felt that he can take over for proper execution of austere or manual operations. His only data entry device is a keyboard and thus data entries of identification and destination for each aircraft under his command will be extremely time consuming.

No controller procedures for the local/ground controller interface have been developed. At the present time, the STRACS display and keyboard design has considered only the requirements of the ground controller. No consideration has been given as to how the local controller interfaces with the display console.

Still some questions exist concerning the reliability of the detection loops and the guidance lights. Concrete pavement failures have occurred where the loops have been installed at JFK behind the Pan American Building. Also, the guidance lights presently anticipated for use in STRACS fail due to snow and sand.

A major limitation of a full automated STRACS system is high cost. The following cost list estimate has been developed for JFK and for a medium sized airport such as Logan. JFK costs are estimated to be $8.4M and Logan costs $3.0M.

COSTS

The following cost list estimate has been developed:

1) Signal lights - 1000 lights at $600 per light.

   This includes the installation in the runway and represents a fairly accurate cost figure.

2) Loop sensors - 1000 loops. Installation cost of two experimental loops was $3000. LFE estimates that loop cost is $200 (good figure) and loop installation could go as low as $500. PONYA feels that loop installation will fall in the $1000 to $1500 ballpark. For the purpose of the estimate that follows, $1000 will be used for installation cost.

3) Remote controllers - 30 intersection units at $5000/$7000 each.

4) Control computer - with interface equipment $400K.

5) Software - $400K.

6) Display - $30K.

7) Engineering Charge for supervision, overhead and debugging of system - 20%.

8) One year maintenance - $100K.

COST SUMMARY (JFK)

1)	Lights	$600,000
2)	Installed loops	1,200,000
3)	Remote controllers	180,000
4)	Computer	400,000
5)	Software	400,000
6)	Display	30,000
7)	Power and communications cable (138,000 ft. at $30/foot)	4,130,000
8)	Engineering, contingency, spares (20%)	1,390,000
9)	One year maintenance	100,000
	TOTAL	$8,430,000

LOGAN COSTS FOR STRACS IMPLEMENTATION

1)	200 installed loops at $1000 each for airport	$200,000
2)	400 guidance lights at $600/light	240,000
3)	27 yellow lights at $600	16,000
4)	125 red lights at $600	75,000
5)	13 intersection controllers ($5000/$7000)	91,000
6)	Display	20,000
7)	Computer	300,000
8)	Software	200,000

9) Power and communications cable (50,000 ft. at $30/foot)		1,500,000
10) Engineering charge for supervision, overhead and debugging of system (20%)		490,000
11) One year maintenance		50,000
	TOTAL	$3,000,000

Other considerations are:

1) Its inability to grow into a CAT III B or C control system without great expense. Currently, there are sensors and stop bars at nodes. If CAT III B operations are conducted a stop bar and sensor may be required every 300 ft. at a cost of $2,800 per installation. In addition, the STRACS system does not regulate traffic in the apron area or in the holding pads.

2) The current software provides only fixed routes for any pair of active runways.

3) Aircraft identification is implied from tracking.

4) Manual intervention by the controller to change signals or priorities is impossible.

5) Velocity estimation or control is impossible.

6) Traffic congestion is not apparent to the controller until after traffic has stopped.

7) There is no way to discriminate between trucks and planes.

SUGGESTED STRACS WORK TO BE DONE

<u>Summary</u>

.detailed cost analysis

.operational analysis of impact of STRACS on tower operations

.re-examination of subsystem designs

<u>Discussion</u>

A detailed cost analysis for a STRACS implementation at JFK is required. At the present time, power and communications cable cost estimates are approximately 50% of the total implementation costs. However, these estimates have been made without the availability of a firm power system design and a detailed analysis of the PONYA facilities at JFK.

An operational analysis of the impact of STRACS on tower operations is needed. The man/machine interface is inadequate because of a poor backup mode and poor data entry capabilities of the display and control console and no operational procedures for the local/ground controller interface have been developed.

A re-examination of the STRACS subsystem designs should take place. Because of reliability and maintenance problems, is the guidance and control subsystem adequate? A technology assessment of visual signal lights should be made including operational field tests. Can radio wave data links be used instead of hardware communication lines in order to reduce the communication calling costs?

Other suggested considerations are:

1) Include velocity information as well as the count of aircraft between nodes. Under poor visibility conditions, the count does not indicate flow conditions.

   The addition of velocity control would tend to give the system the ability to anticipate and avoid undesirable events, such as stopping at intersections and rapid decelerations to avoid conflict with other aircraft under poor visibility conditions.

2) Require that airline personnel enter departing aircraft into the STRACS system at the Central Computer Terminal Area (CTA) so that automatic entry of aircraft into the CTA can occur with a discrete from an inductive loop. This should reduce the controller workload demanded by STRACS.

3) Establish a STRACS ground vehicle communication link for the rejection of ground vehicle signals into the routing system.

4) Incorporate automatic checkout electronics into the induction loop detectors for fault detection.

APPENDIX C
RADAR BASED SYSTEMS

INTRODUCTION

Surface Detection Equipment (ASDE) radar provides controllers with a means to observe and control surface traffic on an airport including operations under low visibility. From the system evaluation tests, it has been concluded that the present ASDE can increase safety and help expedite traffic flow but fails in achieving fundamental requirements: to display the details of an airport with sufficient definition or resolution so that it can supplement or replace the visual observations of a control tower operator. This means that the original performance objectives are still to be achieved, that runways and taxiways be clearly defined and that objects on these areas be plainly visible. Present studies indicate that ASDE only makes important contributions to expediting operations where arrivals and departures use intersecting runways, but plays a rather secondary role in the surveillance and control functions.

STATUS

The control of traffic on the surface of an airport has long been recognized as a part of the overall problem of aircraft traffic control and safety. At the end of World War II the Air Force Watson Laboratory Studies concluded that radar appeared to offer the best and the simplest approach. The highest practical frequency was decided at that time to be used to achieve a narrow azimuth beamwidth, and that frequency was 24 GHz. Atmospheric attentuation studies were done at Mitchell AFB and it was concluded that it would not seriously impair the operation of such a radar at the short ranges involved.

The first AF radar AN/CPS-8 was built at that frequency. After satisfactory evaluation, modifications to the design were proposed and incorporated in the experimental model of ASDE. On completion this experimental radar was evaluated at various AF bases, specifically at the CAA Technical Development Center at Indianapolis and later tested at Rome AFDC. Among the major deficiencies were: (1) lack of picture stability in the PPI; (2) frequency control and unstable operation of the magnetron at the highest prf; and (3) excessive backscatter from rain up to 2000'.

In 1952, the first experimental ASDE was installed at JFK where controllers found it convenient and reassuring to glance frequently at the display at night or during periods of poor visibility, and make some improvement in their operational procedures based on information learned from ASDE. An engineering model initiated in 1953 proceeded with a thorough design review in light of other radars available then such as 16 GHz and 35 GHz radars. 24 GHz radar was favored with 100 MHz IF frequency primarily because of the experience gained from the previous work. Considerable effort was devoted to radome development beginning with a spherical air-inflated and then with a rigid radome.

Also, considerable effort was made on remote operation, particularly on the method of transmitting 100 MHz video. An engineering radar model was completed in 1955 and evaluated by WP AFB. The Federal Aviation Agency (FAA) in 1959 placed an order for 10 radars which at that time were known as model AN/FOM-31. The Air Force developed, tested and approved radar with the only difference being its application philosophy. ASDE was installed in 1960 and has been in operation for eleven years in eight major and four minor airports. A bright display became available in 1966/67. The total radar installation including the radome and self-supporting tower was about $470K each with an annual maintenance cost of $52K of which $40K were for the 100 tubes. Of the total, antenna was $135K and with supporting tower, $210K. For the design improvements so far, the amount spent has been as follows:

Magnetron Development	$450K
Modification to the Circuitry	62K
Duplexer Development	100K
Bright Display Development and Production	500K (12 units)
Bright Display Evaluation	50K
	$1,162K

Radome development is not included in this amount.

LIMITATIONS

A design of ASDE-II radar was originated and completed during the technology advancement stage when RF amplifiers (particularly at K-band frequencies), transistors and ferrite devices were just becoming known and available. Therefore, considering available technology, the ASDE-II radar design may be considered an excellent design and it still has the best resolution among the present-day contenders.

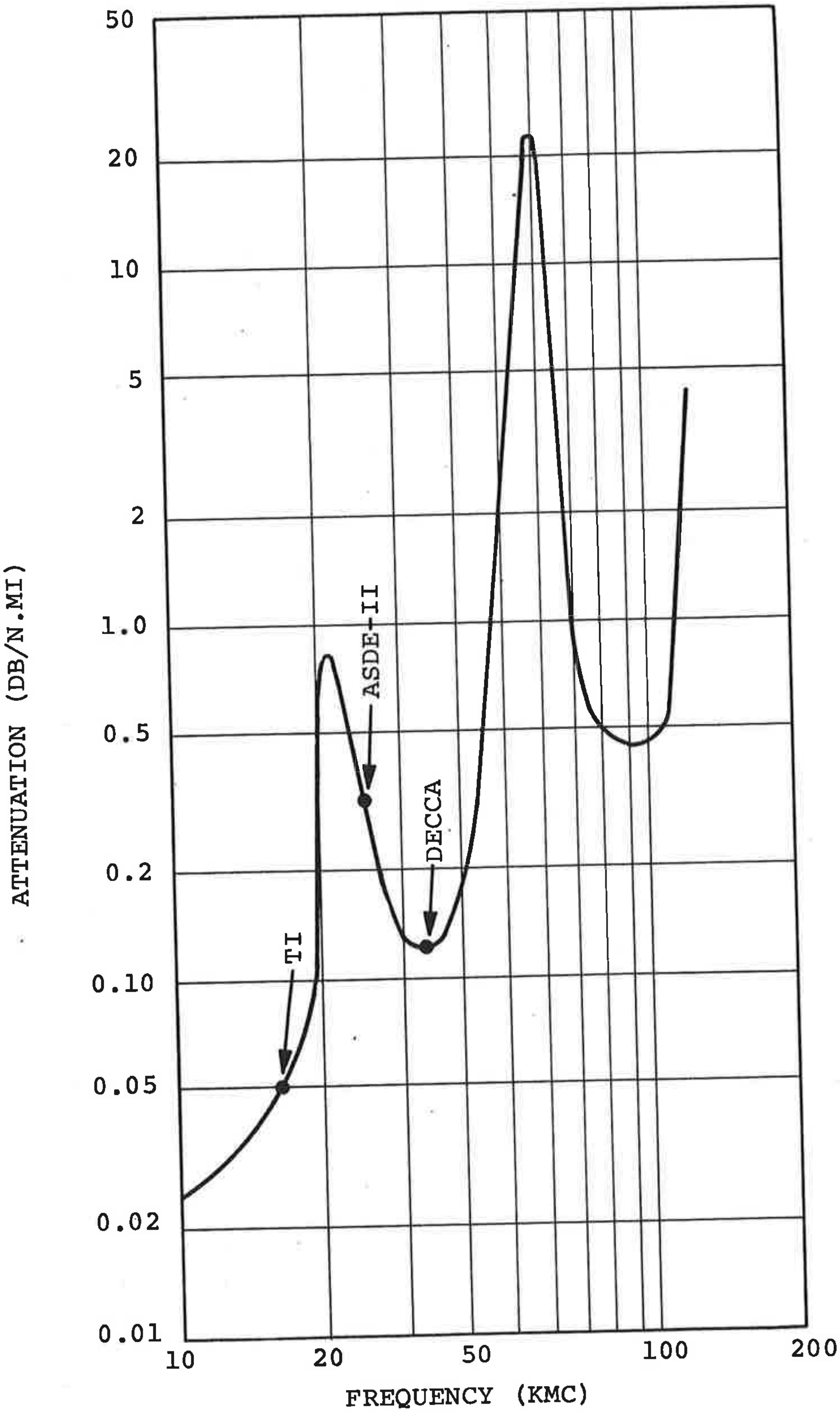


Figure C-1. Total Atmospheric Attenuation (Sea Level)

While discussing the ASDE-II design and design limitations, it is important to recognize what limitations ASDE-II radar has in comparison to DECCA or TI radars. In total, there are three major factors to be considered: (1) atmospheric attenuation; (2) path attenuation in rain; and (3) backscattering from rain. The first two limitations are easily solved by increasing transmitting RF power in the magnetron or developing a more sensitive receiver, but the last one is of the greatest concern to the design engineer.

To justify any validity in a choice of 24 GHz frequency for ASDE-II radar because of atmospheric absorption within a vicinity of the spectrum (water vapor absorption line at 22.4 GHz), a relative absorption graph for all three radars is shown.

A signal loss for the two-way path attenuation for one mile range at 16.6, 24 and 35 GHz are shown in clear weather and heavy rain.

35 GHz - 0.24 (5.38%) db (clear weather)	-13.4 (95.4%) db (rain)
24 GHz - 0.60 (12.9%)	-8.0 (84.2%)
16.6 GHz - 0.10 (2.3%)	-4.2 (62.0%)

From the results it is obvious that radar operation in rain is to be the dominating factor because of its much higher path attenuation.

Contrary to the general belief, backscattering, not path attenuation, is the limiting factor for target detection and resolution provided that the resolution cell of operating radar has already been reduced to the optimum size. In each resolution cell of the total volume, V = (Range times azimuth BW) x (Range times elevation BW) x ($\frac{CT}{2}$ (pulse length)). Three signals are competing: (1) backscattering from the volume of rain; (2) backscattering from the target; and (3) backscattering from the projected ground surface. A simplified relationship between critical parameters is given as follows:

$$\frac{S}{C} \text{ (signal to clutter)} = k \frac{\gamma}{\eta} \tan \phi$$

γ = backscattering coefficient from the surface or target

ϕ

η = backscattering coefficient per unit volume of rain

Using this relationship, we may establish the boundary at which the clutter or backscattering overwhelms the signal reflected from the target.

This simple relationship also explains undesirable clutter or whitening effect for the near targets displayed on the PPI. It is an inherent deficiency in the ground mapping radars where cosecants - square beam is being used to produce a uniform power reflection from all distances and to avoid antenna scan in elevation. As a result, for the near targets resolution volume, clutter backscattering coefficient is significantly greater in comparison with a projected ground surface area. The only reasonable remedy for this problem is more directive antenna beam and antenna scan in elevation.

SUGGESTED IMPROVEMENTS

Suggested improvements for the ASDE-II Radar System are to refurbish the existing ASDE-II radar and add a solid state receiver and direct view bright display.

ASDE-II MODIFICATIONS

1) Bright Display - Performance of the present ASDE-II bright display is not adequate and a new approach to improve it is being suggested. A Hughes storage tube with a single writing gun, two flooding guns and a step video eraser displayed on a 21-inch picture tube may be acceptable. Using this approach in addition to the bright display, a useful history of the target is also provided. Some new design will be required to provide a binary sweep generator for the short range display.

2) Signal-to-Noise Improvements - The following improvements are proposed for the present receiver design:

   a) RF Amplifier - Parametric Amplifier

   b) Balanced Mixer - Schottky Balanced Mixer

   c) Solid-State Duplexer - 4-port Circulator and Limiter

   d) IF-Preamplifier at GHz frequency range

   e) Solid State Receiver

Without losing continuity it may be useful to look at the general radar equation for the ground mapping application:

$$\frac{S}{N} = \frac{G^2 \lambda^2 P_t \theta (c\tau/2)\, \sigma_o (n E(n))}{(4\pi)^3 K T B F_R L R^3 e^{2\alpha R}}$$

$\frac{S}{N}$ - signal to noise ratio

P_t - peak transmission power

F_R - receiver Noise Figure

L - transmission line loss (from the antenna to the mixer)

For the same signal to noise ratio and distance, the equation is simplified to show three parameters to our immediate concern:

$$\frac{S}{N} = K\frac{P_t}{F_R L}$$

We may reduce Klystron power P_t by reducing receiver Noise Figure and/or loss of the transmission line.

To illustrate noise reduction in the receiver when an RF amplifier is being used, the resulting Noise Figure of the receiver becomes a function of the amplifier gain and the mixer loss immediately following the first stage:

$$F_R = F_A \text{ (RF amplifier)} + \frac{F_B \text{ (Balanced Mixer)} - 1}{G_A \text{ (Gain of the RF amplifier)}}$$

If sufficient gain is obtained, 10 db or better for the practical application, Noise Figure of the RF amplifier becomes the receiver Noise Figure of the sytem. This reduction may be very significant in ASDE-II application.

Any loss proceeding RF amplifier directly adds (in db) to the receiver noise; this includes the loss of RF Duplexer, Antenna, etc.

$$F_T \text{ (system)} = L \text{ (Transmission Line)} + F_R$$

3) Solid State Receiver - Considering the high maintenance costs ($40K per year for the present 100 tube design) a solid state receiver may alleviate maintenance problems greatly. While this improvement is implemented, additional receiver functions such as signal processing for clutter reduction, background suppression and target tracking should be implemented preferably in digital form.

Solid state receiver design may still use circular polarization for the rain clutter rejection and/or may incorporate other established clutter rejection techniques.

APPENDIX D

THE INTERIM LOOP DISPLAY SYSTEM AT JFK

INTRODUCTION

An immediate question exists: what to do with the Interim Loop Display System at JFK? To answer this question satisfactorily, a brief background leading up to the development of the system is presented with our recommendations.

BACKGROUND

The initial motivations for the ILDS were proposed airport expansion, construction of new high-rise buildings, and the continuous demands for installation of a new control tower. These demands were accented by the increased traffic and the introduction of B747, L500 and other aircraft. The Port of New York Authority initiated development of a Surface Traffic Control System which automatically manages the movement of vehicles and aircraft on the airport taxiways. The ILDS was developed by NAFEC as an interim aid, designed to provide the GC with a visual display of aircraft or vehicular movement in the blind spot area opposite the Pan American Terminal complex at JFK. The PONYA was to install the ground sensors and remote data to an interface point in the control tower structure. Installation and maintenance of the display system was to be accomplished by the Eastern Region. The prototype ILDS consisted of a series of 15 feet by 45 feet loops, 28 loops in total within 1200 feet taxiway placed 150 feet apart with some exceptions. The total system consisted of three major parts: logic unit, display unit and control unit. Single and paired loops were installed in the vicinity of Taxiways "I", "L" and "O" adjacent to R/W 13R-31L. Only one loop in the system has failed so far.

Finally, to overcome blind spot difficulty, a prototype system was developed and implemented at JFK, but failed to achieve its primary objectives: (1) the system is not reliable because false indications have occurred. The cause, however, has not been established. Changes in the inductive loops and/or detector electronic characteristics can cause a false signal. The inductive loop characteristics do change with water, temperature, and motion of the pavement. This reduces the reliability of the loop and detector combination. (2) the system can only operate when traffic enters and is moving in the traffic restricted directions. Any intruder in the system by an accident confuses the logic, (3) Intersections are insensitive to vehicles while the initial vehicle is still present. Some modifications were initiated by the NAFEC to alleviate deficiencies detected during the prototype testing. Also, NAFEC engineers are preparing an evaluation report on the present system yet to be made operational for FAA Headquarters. A draft of the report is due within two weeks and may be available from FAA on request.

RECOMMENDATIONS

The following three major recommendations to the ILDS are suggested:*

1. To use the present prototype ILDS explicitly to check hardware and system performance for STRACS with specific emphasis on system reliability and the false alarm effect.

2. Develop a blind spot detection system for use at airports with blind spot problems by modifying the present design: (1) by increasing loop sensitivity and (2) modifying the systems' logic to achieve a greater flexibility in system and to perform additional functions.

3. Implement a Local Intersection Control or STRACS Austere Mode by adding adequate data processing to the modified ILDS.

*Recommendations 2 and 3 are made with some reservations. The problem with recommendation 2 is that controllers at JFK are reluctant to break their airport wide scan pattern to look at a display that gives them incremental information only about a model port of the airport. The reservation for recommendation 3 is as described in page 18 of the main body of the report.

DESIGN APPRAISAL

Detailed design review on ILDS was done and is presented in this appendix. The following are the major areas which need design improvements.

1. The present ILDS may fail to detect the whole body of the aircraft reliably, i.e. B747 and others.

2. ILDS algorithms are designed to satisfy controlled entry into the system and are followed by controlled traffic movements, but may fail should another vehicle enter the system in the opposite direction accidentally.

3. Present ILDS will not detect another vehicle entering an intersection while the first vehicle is still in the loop.

4. ILDS should be designed to fail safe, i.e. positive pulse indicates no vehicle present.

TECHNICAL APPROACH

Recommendations based on the present study, availability of the installed loops and motivation by the various interest groups may be satisfied by implementing the following tasks:

TASK 1. Use of the existing prototype system for testing reliability of the hardware and the false alarm rate.

1. Conduct a real-time reliability check of the system by monitoring traffic flow in the system from the advantage point such as Pan American building where all entries and exits of vehicles are observed.

2. Use ILDS to test hardware and system performance for STRACS. Also, to test the major problem as reported by the NAFEC that water accumulation has caused a positive indication of an aircraft.

TASK 2. Modify the Prototype ILDS.

1. Present detection loops may require a modification to enhance the sensitivity of the system. In addition algorithms and the logic for the Prototype ILDS must be redesigned to achieve greater flexibility in operation and reliability.

2. Adapt modified ILDS for a blind spot detection system for airports with blind spot problems.

TASK 3. Improved ILDS with a Data Processor.

1. Add required data processor to the modified ILDS to test Local Intersection Control or STRACS austere mode functions.

CRITIQUE OF INTERIM LOOP DISPLAY SYSTEM

Criticisms of this system fall into two categories:

1) Systems Concepts

2) Hardware Implementation

DISCUSSION - CATEGORY 1

1) It might be possible to sense direction with one loop if proper attention is paid to interfacing circuits. This would simplify the logic design and solve many ambiguous situations. This is an area worth additional effort.

2) Interfacing circuits (between loops and logic) are critical and much depends on their operation. It would be very helpful to review these, i.e.:

    a) What happens when lightning strikes a loop?

    b) Are loops sensitive to outside interference?

    c) Do they radiate energy of their own or re-radiate reflected energy?

    d) Can the interface circuits discriminate against noise?

3) Human factors considerations seem awkward. The operation of the logic seems to burden the ground controller with unnecessary restrictions in directing traffic on the taxiways, or is it simply airport operational ground rules -- it is not clear. A discussion with the user would be essential for a finished design, i.e.;

    a) Aircraft ought to be able to reverse direction midway on a taxiway, as long as they do not pass other aircraft in the opposite direction.

    b) With proper logic, most intruders can be recognized and displayed without error.

    c) Also, it is possible to detect an impending collision. This is a useful feature!

    d) Vehicles should be allowed to cross different loops simultaneously, but no two vehicles can cross the same loop simultaneously.

CATEGORY 2

As evident from the description in the instruction manual, the design approach is a "cut and dry" procedure. It would be very difficult to trace out the paths of potential logical errors.

Therefore, it was decided not to try to analyze the existing design, butt to indicate the universally accepted procedure for the logic design of this type of interface logic.

Logic has been designed for one block. All blocks would simply be a reiteration with successive designations. Included are the "standard basis" with variable mapping and the resultant boolean algebraic equations.

Series 7400 TTL logic is rapidly becoming the least expensive, most popular and versatile (in logic functions) of any logic family and is sourced by a half dozen manufacturers. The existing hardware uses Motorola DTL which is currently more expensive and has fewer logic functions available.

The following comments apply to the hardware as it exists:

1) The lamps need not be driven with relays, eliminating a power supply and 68 relays and the separate relay drivers. A lamp may be driven with ganged 7440 buffers. Lamps should have "keep alive" resistors.

2) A rotating electro-mechanical device for testing is archaic. This should be replaced with up/down counters.

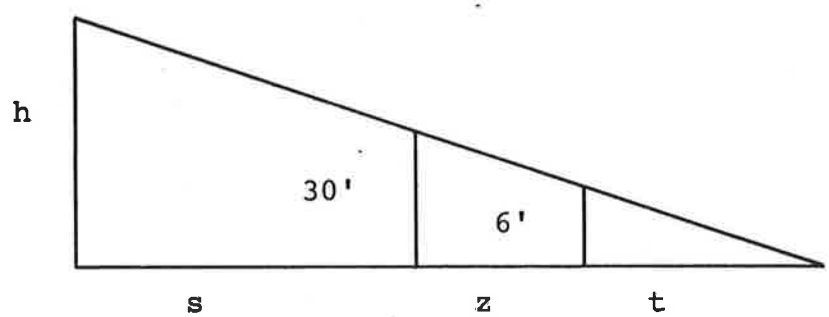
3) The block memory, synchronous 3-stage counter should be replaced with a simple shift right/left 4-bit register.

4) The logic chassis is excessively big and heavy; it can be reduced considerably by multi-socket I.D. boards with wire wrap terminals also providing easy modification usually required in prototypes.

5) GLITCH DODGING with resistors and capacitors is both unnecessary and unreliable.

APPENDIX E
TOWER LINE OF SIGHT CALCULATIONS

I. Derivation of Calculation of Line of Sight Shadowing



h = tower height
s = distance from tower to 42 MSL
z = distance to 6 ft. viewing point

By similar triangles

$$\frac{h}{30} = \frac{s+z+t}{z+t}$$

1) $\therefore \quad z+t = \frac{30s}{h-30}$

By similar triangles

2) $\frac{30}{z+t} = \frac{6}{t}$

$$t = \frac{z+t}{5}$$

3) $\therefore \quad t = \frac{6s}{h-30}$

Solving for z from Eq. 2 and substituting for t from Eq. 3

$$z = \frac{24s}{h-30}$$

For 6 ft.

$$z = \frac{24s}{h-30}$$

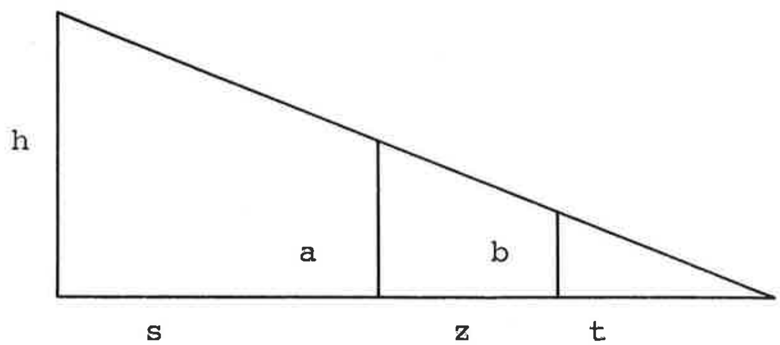
For 4 ft.

$$z = \frac{26s}{h-30}$$

For 7 ft.

$$z = \frac{23s}{h-30}$$

II. Derivation of Calculation of Movement of the 42 MSL Line



h = tower height
s = distance from tower to new 42 MSL
z = distance to b ft. viewing viewing point

s+z = distance from tower to inner taxiway

By similar triangles

1) $$\frac{h}{s+z+t} = \frac{a}{2+1}$$

2) $$x+t = \frac{as}{h-a}$$

from Eq. 2

$$x = \left(\frac{a-b}{h-a}\right) s$$

adding s to both sides of the equation gives

$$s = \left(\frac{h-a}{h-b}\right) \left(z+s\right)$$

III. Calculations

A. 4 Ft. Object

Tower Height 250 ft. (all numbers in ft.)

Terminal Building	Dist.from 42 MSL to Tower	Dist.from 42 MSL to Taxiway	Dist.Blind Behind 30' Bldg. at 42 MSL	Over-lap	Corrected Tower Dist. to 42 MSL	Change in 42 MSL Line
PAA	2500	250	294	44 ft.	2459	41
EAL	3300	365	389	24	3278	22
UAL	3900	400	463	63	3845	55
AAL	3700	400	436	36	3667	33
AAL	3440	400	406	6	3434	6
BOAC	2700	328	319	-9		

Tower Height 275 ft.

PAA	2500	250	265	15	2486	14
EAL	3300	365	349	-16		
UAL	3900	400	413	13	3887	13
AAL	3700	400	392	-8		
AAL	3440	400	363	-37		
BOAC	2700	328	285	-57		

Tower Height 300 ft.

PAA	2500	250	240	-10
EAL	3300	365	317	-48
UAL	3900	400	374	-26
AAL	3700	400	355	-45
AAL	3440	400	330	-70
BOAC	2700	328	260	-68

B. 6 Ft. Object

Tower Height 250 ft.

PAA	2500	250	272	22	2479	21
EAL	3300	365	360	-5		
UAL	3900	400	428	28	3876	24
AAL	3700	400	403	3	3696	4
AAL	3440	400	375	-25		
BOAC	2700	328	295	-33		

III. Calculations (Continued)

Terminal Building	Dist.from 42 MSL to Tower	Dist.from 42 MSL to Taxiway	Dist.Blind Behind 30' Bldg. at 42 MSL	Over-lap	Corrected Tower Dist. to 42 MSL	Change in 42 MSL Line
Tower Height 275 ft.						
PAA	2500	250	245	-5		
EAL	3300	365	323	-42		
UAL	3900	400	382	-18		
AAL	3700	400	362	-38		
AAL	3440	400	336	-64		
BOAC	2700	328	264	-64		
Tower Height 300 ft.						
PAA	2500	250	222	-28		
EAL	3300	365	293	-72		
UAL	3900	300	346	-54		
AAL	3700	400	328	-62		
AAL	3440	400	305	-95		
BOAC	2700	328	240	-88		
C. 7 Ft. Object						
Tower Height 250 ft.						
PAA	2500	250	259	9	2489	11
EAL	3300	365	343	-22		
UAL	3900	400	409	9	3890	10
AAL	3700	300	385	-15		
AAL	3440	400	359	-41		
BOAC	2700	328	281	-47		
Tower Height 275 ft.						
PAA	2500	250	234	-16		
EAL	3300	365	308	-57		
UAL	3900	400	365	-35		
AAL	3700	400	346	-54		
AAL	3440	400	320	-80		
BOAC	2700	328	251	-77		

III. Calculations (Continued)

Terminal Building	Dist. from 42 MSL to Tower	Dist. from 42 MSL to Taxiway	Dist. Blind Behind 30' Bldg. at 42 MSL	Over-lap	Corrected Tower Dist. to 42 MSL	Change in 42 MSL Line
Tower Height 300 ft.						
PAA	2500	250	212	-38		
EAL	3300	365	280	-85		
UAL	3900	400	330	-70		
AAL	3700	400	314	-86		
AAL	3440	400	291	-109		
BOAC	2700	328	230	-98		

IV. Weather Considerations for JFK

400'

CAT I = 184 hrs/yr

200'

200'

CAT II = 67 hrs/yr

100'

100'

CAT III = 62 hrs/yr

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a = CAT III hrs = 62 hrs/yr
b = CAT II hrs = 67 hrs/yr
c = CAT I hrs = 184 hrs/yr

145 ft. Tower Height

$$\text{Total hrs} - a + \frac{45}{100}(67) = 92 \text{ hrs}$$

250 ft. Tower Height

$$\text{Total hrs} = a + b + \frac{50}{200}(184) = 175 \text{ hrs}$$

275 ft. Tower Height

$$\text{Total hrs} = a + b + \frac{75}{200}(184) = 198 \text{ hrs}$$

300 ft. Tower Height

$$\text{Total hrs} = a + b + \frac{100}{200}(184) = 221 \text{ hrs}$$