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VISUAL CONFIRMATION OF VOICE TAKEOFF CLEARANCE (VICON) ALTERNATIVE STUDY

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16. Abstract

This report presents the results of a program undertaken to study potential alternatives to the VICON (Visual Confirmation of Voice Takeoff Clearance) System which has undergone operational field tests at Bradley International Airport, Windsor Locks, Connecticut since October 1979. The tests are scheduled for completion in March 1980.

This report presents alternatives from two different viewpoints namely, those alternatives that can improve certain key components of the existing VICON System, and those proposing entirely different concepts than the current concept.

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PREFACE

As a result of the accident which occurred at Tenerife (Canary Islands) killing 583 people and destroying two 747 aircraft, the Federal Aviation Administration (FAA) undertook a program called VICON (Visual Confirmation of Voice Takeoff Clearance) designed to test and evaluate a system using a secondary stimulus, light, to provide a confirmation of voice takeoff clearance signal to the aircraft. The VICON system was installed at Bradley International Airport, Windsor Locks, CT. In the event the VICON system installed at Bradley was found inadequate to the user community or required modifications to improve system performance and reduce costs, the FAA requested that TSC (Transportation Systems Center) undertake a VICON alternative study program.

This report describes various VICON design concepts and modifications to the existing VICON system aimed at providing a system with improved performance and acceptability to the user, in this case, the aircraft pilot and the local controller. The report specifically describes VICON concepts that differ from the existing visual (signal light) concept such as placing a confirmation of takeoff clearance signal in the cockpit using DABS (Discrete Address Beacon System) or modifications to the existing VICON system using new light sources, control/display and state-of-the-art solid state techniques.

The author wishes to acknowledge those most helpful in contributing to this report either by conveying new ideas or criticism to the original manuscripts. Special thanks are given to F. Mackenzie, TSC; J.R. Coonan, TSC; and John W. O'Grady, TSC, who conveyed ideas related to the material presented in this report and also critiqued the report. In addition, special thanks must be given to George A. Scott, ARD 422; William F. Petruzel, ARD-111; FAA program and assistant program managers for their suggestions and NAFEC (National Aviation Facilities Experimental Center) Personnel, Bret Castle, Alan Novakoff, John J. Maurer, and Felix F. Hierbaum, Jr., for providing some of the technical information used in this report.

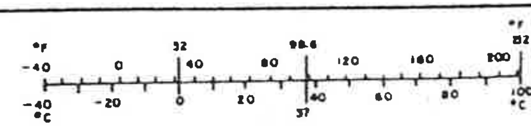
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 SCOPE

This report presents the results of a program undertaken by the Transportation Systems Center (TSC) for the Federal Aviation Administration (FAA) to study potential alternatives and/or changes to the specific VICON (Visual Confirmation of Voice Takeoff Clearance) System which has undergone operational field tests at Bradley International Airport, Windsor Locks, Connecticut, since October 1979. The tests are scheduled for completion in March 1980.

This report presents alternatives from two different viewpoints, namely, those alternatives that can improve certain key components of the existing VICON system and those proposing entirely different concepts than the current concept. Estimated costs for developing various alternatives presented in this report will be given wherever possible.

Since this report cannot cover all possible alternatives that can be conceived for the VICON application, it is hoped that the material presented here will stimulate ideas from the reader which may contribute to the definition of future alternatives to the present VICON system where required. The reader should understand that certain alternatives have sufficient technical capability to perform other functions in addition to the VICON function. In fact, the cost of developing and using high technology system alternatives can be more easily justified if they are multi-functional, i.e., if they are used to perform other functions relating to airport surface traffic problems. Depending on the results of the Bradley tests, it may be necessary to consider one of the various alternatives that will be discussed in this report as a possible candidate for a take-off clearance confirmation system in spite of its technical sophistication and costs. The goal is to provide the user community with a safe, efficient, and reliable visual confirmation of voice takeoff clearance system. If this is the only method for preventing another Tenerife type accident from recurring, then the cost, effort, and technical development are warranted.

1.2 BACKGROUND

The VICON program was initiated by the FAA as a result of the Tenerife (Canary Islands) accident which killed 583 people and destroyed two 747 aircraft. The primary cause of the accident was attributed to an unauthorized takeoff due to a misunderstanding of a voice takeoff clearance instruction.[1,2*] It was felt that perhaps a second independent sensory stimulus, a visual signal, which would be used as a confirmation signal to the voice takeoff clearance instruction might prevent another accident such as the one at Tenerife.

A simple system using a cluster of pulsating green lights placed at each departure location and operated through a selector panel at the local control position in the tower was selected to be tested under operational conditions at Bradley International Airport. Control signals for this system will be both hardwired and radio frequency (RF), equipment for the latter to be installed only at the ends of runways 6, 24, 15, and 33. A more detailed description of the Bradley Vicon system is given in previous VICON reports.[3,4]

A system similar to the Bradley system was tested at NAFEC prior to establishing the VICON design concept for Bradley. The NAFEC system initially used standard highway traffic signals for the VICON lights and a mimic panel located in the tower cab as the control panel and display. Only two runway ends and a single intersection were equipped with lights. The standard highway traffic signal lights were found inadequate and were replaced with a cluster of three green pulsating lights.

The results of the tests at NAFEC revealed the following:

1) The standard traffic signals used at NAFEC were not suitable as VICON lights. The pulsating green light

*See Section 12, References.

clusters were then developed, and when tested, proved favorable.

2) The system needed to be tested in a complete operational airport environment. All departure locations should be equipped.

3) The inductive loop for automatically "turning off" the VICON "green pulsating light" was unreliable and could not be used at Bradley Airport.

4) RF control, microwave sensors and timers for automatically "turning off the VICON lights" were proven to be satisfactory.

5) VICON lights should have a "standard" location at all airports, preferably on the left side of the departure position.

6) An automatic light intensity (photo cell) with override feature is required.

Several design considerations were adhered to in the design of the VICON system. The most important was that the system would function only as a confirmation to the voice takeoff clearance instruction. It would not in itself be a control function. It was to be a simple system that could easily be operated by the controller. The VICON system to be tested at Bradley Airport meets the simple design criteria.

This report proposes system alternatives having characteristics intended to improve performance, reliability, and maintainability as well as boosting user confidence. For example, the Airway Facilities Service (AAF) has already indicated that the production system will have solid state components in order to assure a more reliable and cheaper system. In addition, when the system is to be considered for deployment at all towered airports, close attention will have to be given to special design problems for the tower cab control panel, particularly those associated with fitting it in the controller's console. At larger airports more than one panel may be required, which compounds the tower cab space problem. Coordination and interfacing issues between two local controllers operating the display/control panels will also have to be addressed.

This report considers VICON alternatives from two different viewpoints. Initially, alternative techniques and modifications to key VICON system components are presented. This treatment is solely concerned with methods that are aimed at improving the present VICON system performance. The second viewpoint concerns concepts for providing confirmation of voice takeoff clearance which are different from the present system design concept.

Government, industrial, and university sources in addition to periodicals, books, and technical publications were used as references in developing the concepts presented in this report.

2. PROBLEM DEFINITION

The problem is to develop a simple, reliable, and failsafe system to confirm voice takeoff clearance and use sensory stimuli other than aural. The voice takeoff departure clearance instruction issued by the local controller to the pilot does not, according to present procedural policy, require a pilot response to the controller giving verbatim the takeoff clearance instruction. As a result there can be a misunderstanding of takeoff clearance instructions by the pilot. The objective of the VICON program is to devise a system that will prevent accidents such as the one that occurred at Tenerife.

The VICON system to be tested at Bradley International Airport consists of the following components:

a. VICON lights (pulsating green light cluster)

b. Power sources (110V AC, 48V DC)

c. Control interfaces (Relays)

d. Remote radio frequency (RF) control hardware

e. Hardwired control

f. Automatic light turn-off apparatus

g. Control panel in tower.

The two key components in the group listed above are the VICON lights and the control panel. Acceptance of the VICON system will depend to a large extent on whether these two vital components are deemed satisfactory by the pilots and controllers. The alternatives presented in this report will be particularly important if the Bradley tests confirm the necessity of a VICON type system but indicate that the specific VICON system tested requires modifications or an entirely different design.

3. SYSTEM FUNCTIONAL REQUIREMENTS

The VICON system requirements are as follows:

a. The system shall function as standard departure procedure at all towered airports.

b. The VICON signal (lights) shall be conspicuous to aircraft of all classes.

c. The system shall have minimal user impact (pilots, controllers, and airport).

d. Use of the system shall be as easy as possible.

e. The system shall be operated continuously (24 hours daily or while the tower is in operation) and shall perform adequately under VFR and IFR weather conditions.

f. The system shall operate reliably and only confirm the voice takeoff clearance instruction, i.e., the controller will still be the control authority for granting takeoff clearance authorization.

g. The system shall be compatible with other Air Traffic Control (ATC) systems.

4. TRAFFIC SIGNAL CONCEPTS

Two visual signals, standard highway traffic signal lights, and a pulsating cluster of three green lights (PAR 56 type lamps) have been considered for the VICON application and have been tested at NAFEC. Some standard highway traffic signals were available since they had been used in an automatic intersection control system test performed at NAFEC several years ago and had not been removed from the test bed. It was felt initially that a fast preliminary test using these signals and other control equipment from that program could be made to take a "quick look" at the feasibility of the VICON concept. NAFEC engineers and pilots involved in the tests concluded that these standard highway traffic signals were unsatisfactory. The principal reason given was that the standard highway traffic signals were difficult to see in daylight especially when the sun was at a low angle such that its rays were shining on the lens faces.

The standard highway traffic signal lights using various techniques were tried to improve their visibility to aircraft. The traffic signal light tested at NAFEC was the standard 8-inch diameter unit used in automotive traffic applications. The first bulb used was rated at 100 watts, which is somewhat higher than the 67 watts used for highway traffic applications. The traffic signal used in the automatic intersection control experiments consisted of two sections, one housing a red light and the other a green light. NAFEC replaced the red light with a green light so that the fixture contained a double green light. One of the green lights on the two section traffic signal was replaced with an arrowed green light which signified departure direction for a aircraft entering complex taxiway/runway intersections and was expected to eliminate confusion regarding which end of the runway was to be used for departure. However, pilots felt that the green arrow was difficult to see.

NAFEC engineers tried several techniques to improve the visibility of the standard highway traffic signal light. They tilted the lights at various angles and used hoods, louvers, etc. They positioned the two sectional lights horizontally along the edge of the runway so that the two sections were side by side on a straight line. Eventually the traffic signal was discarded in favor of another approach.

The following discussion suggests some ways the standard highway traffic signal might be improved for the VICON application. Whether or not such signals will ever be considered again for VICON will depend, of course, on how well the pulsating, three-light cluster performs at Bradley International Airport.

The standard highway traffic signal light should be increased to 12 inches in diameter. In addition, the contrast ratio should be increased by using a specially designed black halo around the fixture. This would improve the viewing area and the conspicuity of the light.

The light could also be made to pulsate similar to the pulsation time of the VICON light cluster. Even more important are the special lens systems developed by Minnesota Mining and Manufacturing (3M) Company, as well as others, for highway traffic signals. These systems provide directional viewing, so that only aircraft located in a specific area can observe the light. This can be very important especially on complex runway/taxiway intersections and for aircraft in queue awaiting takeoff clearance. One of the pilot comments during the tests at Washington National Airport in 1966 was that many aircraft awaiting takeoff could see the signal at the same time and were perplexed about whom it was intended.[5] The optically programmed signal manufactured by the Minnesota Mining and Manufacturing Company would be visible only to the airport runway or taxiway area where it must be seen. This is accomplished through the use of a high resolution optical system which is built into the light. Hoods or louvers are not required. Each section of the light can be programmed at the site to restrict visibility of the light very closely to any desired line.

Components of the system are shown in Figure 4-1. The key component is the thin acrylic plastic fresnel lens called an incremental lens. This lens is analogous to a multi-element glass lens system in which corrections have been made for spherical aberrations. The incremental lens forms an image of a 30° viewing area of the intersection to be controlled which is seen on the rear surface of the optical limiter. All light reaching the eyes of the pilot originates from the point on the limiter at which an image of his eyes is seen.

From the pilot's point of view it is similar to looking at a slide projector. From a distance all that can be seen is the color emitted from the projector. If the projector projected red on the screen all that could be seen looking into the projector would be red. Moving to an area which projected a shadow or dark area on the screen, no light could be seen when looking into the projector. This is exactly what happens in the optically programmed signal head.

As the airplane and pilot move, the origination point of light moves accordingly across the limiter. If the limiter surface is masked with an opaque tape in areas of the image corresponding to runway zones where the signal is not to be seen, it is possible to selectively control signal visibility. Very simply by tape masking, light can be put exactly where it is to be seen and virtually eliminated from where it is not to be seen.

As mentioned previously, this type signal can be extremely useful where a complex runway-taxiway situation is encountered, also. It is desirable to avoid confusion on the part of the pilots using these intersections as well as these for whom the confirmation signal is intended. By proper placement of the traffic signal light and masking, such confusion can be eliminated.

The optically programmed signal light is presently being used in automotive traffic applications, especially when new systems are considered. With some minor modifications it is expected that the optically programmed signal light can be adapted for aviation use.

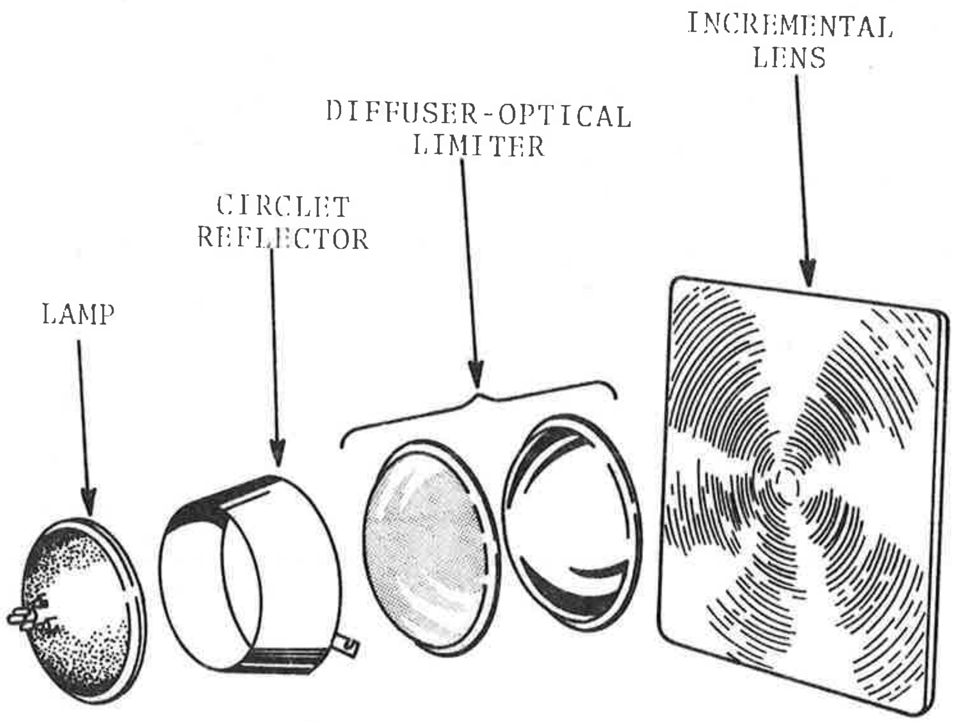

FIGURE 4-1. OPTICALLY PROGRAMMED SIGNAL COMPONENTS

The cost of a single section optically programmed signal light is around 240 dollars with no modifications. Typically, the lamp is rated at 150 watts. Minor modification, such as using a fixture with a frangible coupling, would be required for airport applications. It is believed that several of these lights, appropriately placed to take into consideration the various takeoff situations, can provide an added safety feature for the VICON system.

5. ALTERNATIVES TO TRAFFIC SIGNALS

As previously mentioned the standard highway traffic signal visual source was tested at NAFEC and found wanting. In Section 4, several suggestions were made which may lead to an improved traffic light type signal.

Two alternative visual sensors to the traffic light signal source are discussed here. These are (1) a pulsating light source and (2) signs. The former will be tested at Bradley International Airport and will be the visual signal used at that airport at all departure points. Only signs which are internally illuminated will be discussed as potential VICON source candidates in this report.

5.1 PULSATING LIGHT SIGNAL SOURCE

The light proposed by and tested at NAFEC which will be used in the Bradley field tests is a PAR 56 lamp commonly used as an approach light. It has a green filter and uses a regular incandescent type bulb. The light is rated at 200 watts.

The configuration which will be used at Bradley will consist of a cluster of three PAR 56 lamps (Figure 5-1) pulsating approximately once every seven seconds. The lamps will be in series operating at 6.6 amp and approximately 30 volts/lamp.

The lights are approximately 14 inches high from the surface and are mounted on a frangible coupling. Each light cluster will be placed approximately 500 feet from the end of the runway or runway/taxiway intersection. All light clusters will be located on the left-hand side of the takeoff position. The lights are arranged so that one is aimed directly across the runway, another diagonally across the runway and the third parallel to the runway. This orientation is provided to obtain the maximum viewing field for departing aircraft. The lights will be either located in-line with the runway edge lights or close to the runway edge lights to avoid hindering snow removal operations.

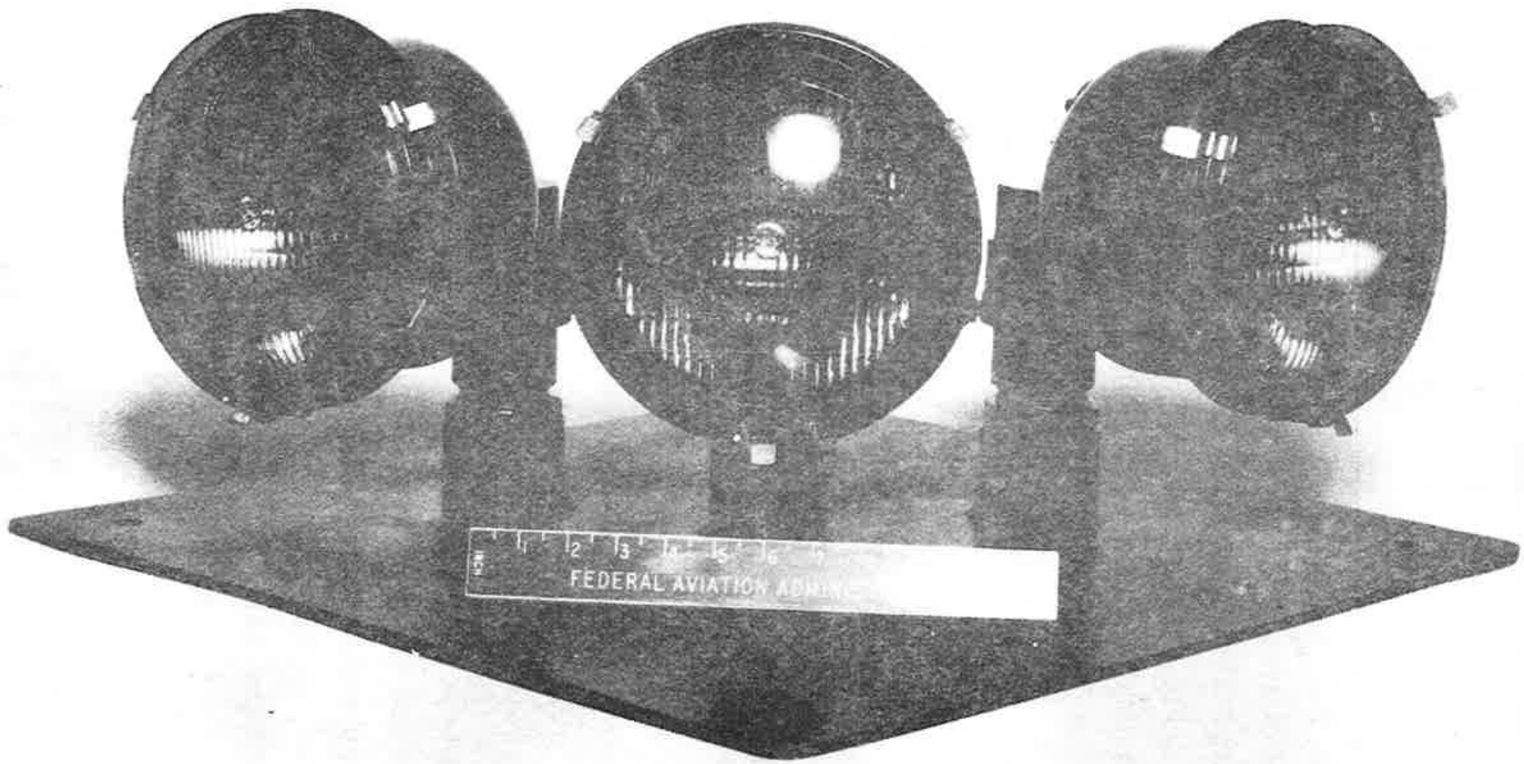

FIGURE 5-1. PULSATING GREEN LIGHT CLUSTER

Although preliminary tests at NAFEC with the three-light cluster showed a significant improvement in visibility and conspicuity over the standard highway traffic signal light, the three-cluster light still may not be the optimum light. For first time users of the airport, additional voice communications between the controller and pilot may be required to explain its function and presence. The principal problem in most cases with any light is that its function is not self-evident. Also from the standpoint of maintenance, considering the myriad lighting problems that are already present on an airport, another light is not necessarily a welcome addition. Any problems that may be inherent in the use of the pulsating, green, three-light cluster should be determined by the operational field tests at Bradley International Airport.

5.2 SIGNS

Signs have been used on airports to provide advisory runway/taxiway identification and destination direction information to aircraft. The two basic types are internally illuminated and externally illuminated. Externally illuminated signs were not considered as a direct replacement for the traffic light for this application primarily because the displayed message should be visible only when the sign is "on." When the sign is "off," the face should be blank. Externally illuminated signs, however, may be used to inform pilots that there is a traffic signal clearance light ahead (informational sign). For the Bradley field tests, an inexpensive informational sign having a yellow background may prove satisfactory. This sign would be hooded when the VICON system is not being tested. For systems to be deployed at other airports where continuous usage is expected, an internally illuminated informational sign may be necessary, since the message should be blank if the system is not in use. The disadvantage of this type of sign would be that control (switching on-off, brightness) would have to be executed by a controller. The field tests at Bradley should determine if an informational sign is required for use with the traffic light signals. The use of an informational message sign is mentioned here in the event the VICON test data collected at Bradley International Airport show it is necessary to provide some method of informing inexperienced VICON system users of the traffic signal light function. This could be done by voice communication but at busy airports that would be undesirable since the voice communication links are already overloaded.

This report, however, is more concerned with the problem of direct substitution of a sign for the light cluster in the event the pulsing light cluster concept proves unacceptable to the users during the Bradley Airport field tests. The most promising alternative candidate would be the lamp matrix message sign. A one or two message display would be sufficient for clearance confirmation.[5] The two messages could be "hold" and "go," or if a single message, "Confirmed for takeoff." The exact message content would determine the cost and size of the sign.

The fixed message sign would be controlled in the same manner as the signal light, i.e., by the local controller. At the present time, internally illuminated signs using matrix type incandescent lamp bulbs have sufficient brightness to be seen in daylight under severe ambient light conditions, i.e., even when the sun is shining directly on the face of the sign. Internally illuminated signs, other than the matrix incandescent lamp, have message "wipe out" under such conditions. The matrix incandescent lamp signs also have a lamp dimming circuit which automatically adjusts the sign illumination for maximum readability in all ambient conditions, day or night. Another feature of this type of sign is that the message can be read without difficulty even if one or two lamps burn out or fail. Since no mechanical parts exist in a lamp matrix sign it is not affected by adverse climatic conditions.

A sign has one outstanding advantage over a signal light. The sign requires no interpretation to understand its message. A signal light on the other hand requires explanation of its function and this can present a problem for VICON users unfamiliar with VICON lights. These lights may require an explanation by the local controller of how the signal lights function. At busy airports, this would further increase controller workload and further burden an already saturated voice communication network. A message sign would not cause such problems. A sign having one or two fixed messages would cost approximately thirty thousand dollars per location, whereas signal light fixtures can be purchased for several hundred dollars per departure location. Although impact on total system costs for a spectrum of airports has not been done, significant added costs would be a disadvantage. Incandescent matrix type signs are manufactured by firms whose primary business is providing commercial and highway signs. Several are listed in Appendix A.

It is recommended that if this approach is considered, a fixed message sign with associated controls and electronics be purchased and tested at NAFEC and then at Bradley Airport. This is necessary in order to determine if a fixed message can be easily read by pilots.

6. DISPLAY/CONTROL PANEL CONCEPTS

The function performed by the display/control panel is extremely important to the controller and careful consideration must be given to its design.

It is difficult to design a display/control panel which is satisfactory to every controller. However, the principal requirements that must be satisfied are that the display/control panel have a minimal impact on controller workload, not distract the controller from his primary duties, and fit into the existing tower cabs and controller environment.

Two types will be tested in the Bradley VICON field tests: the so-called "mimic" type display and the keyboard (matrix) panel type. The mimic type display shown in Figure 6-1 is a visual map of the airport runways and intersections under VICON control with appropriate switches. The keyboard panel (see Figure 6-2) is a panel having switches and lights arranged in a row-column matrix format. The push button switches control indicator lights which, when activated, show the status of the VICON light. Both panels were considered initially because they were simple and the hardware could be fabricated in a reasonable time with off-the-shelf components. However, both concepts, while suitable for Bradley Airport, may have problems related to scaling in size when needed for larger airports where there are more take-off locations. Another panel using touch-sensitive switches will also be tested at Bradley Airport. All the panels can be operated by remote control; i.e., the local controller has a switch control on his person that enables him to control the principal runway take-off positions (ends of runways).

The design criteria for the display/control panel are based on the following factors:

a. The display must have sufficient brightness and contrast to be readily seen under ambient light conditions that exist in the control tower.

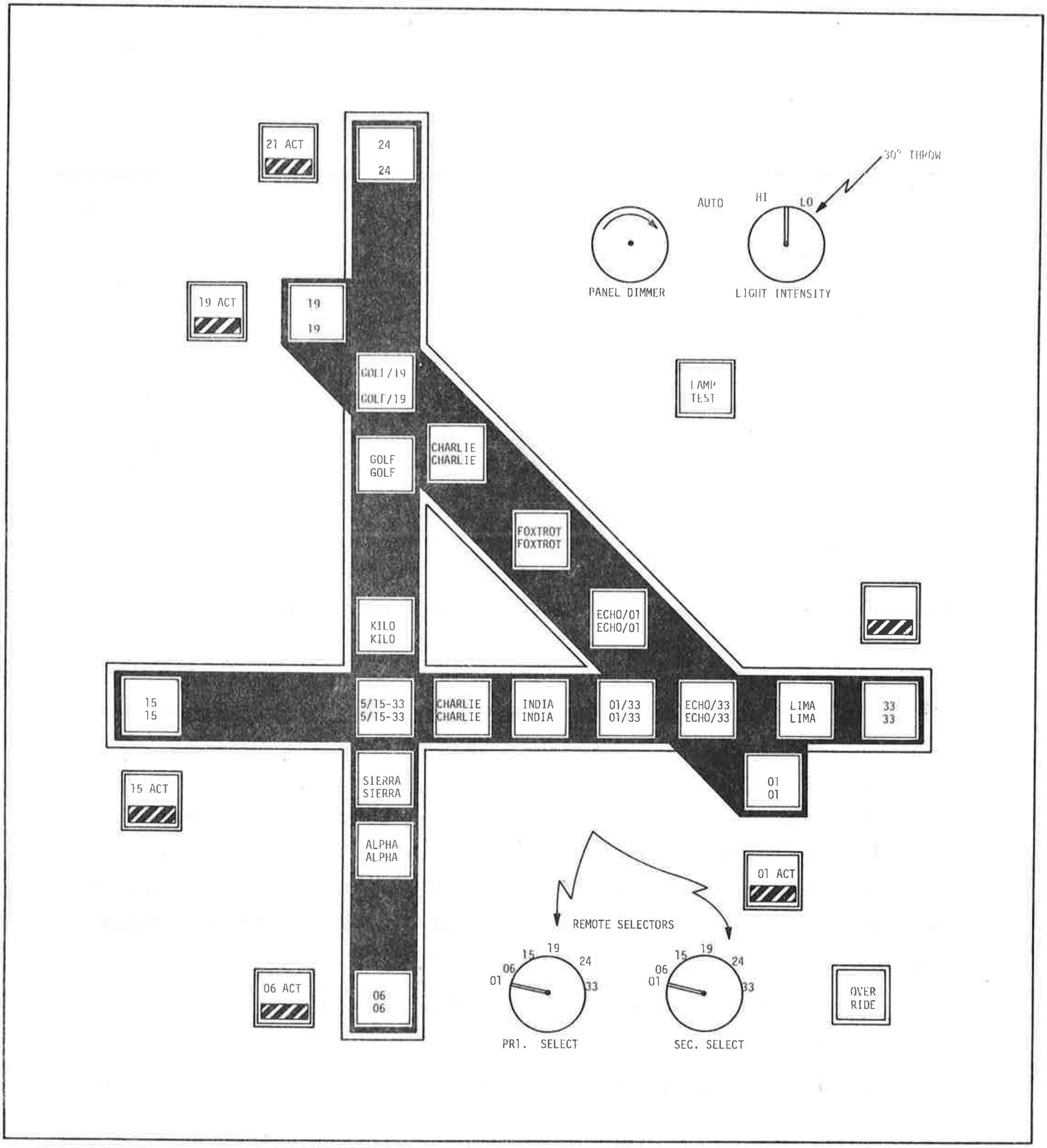

FIGURE 6-1. NAFEC "MIMIC" DISPLAY DESIGN

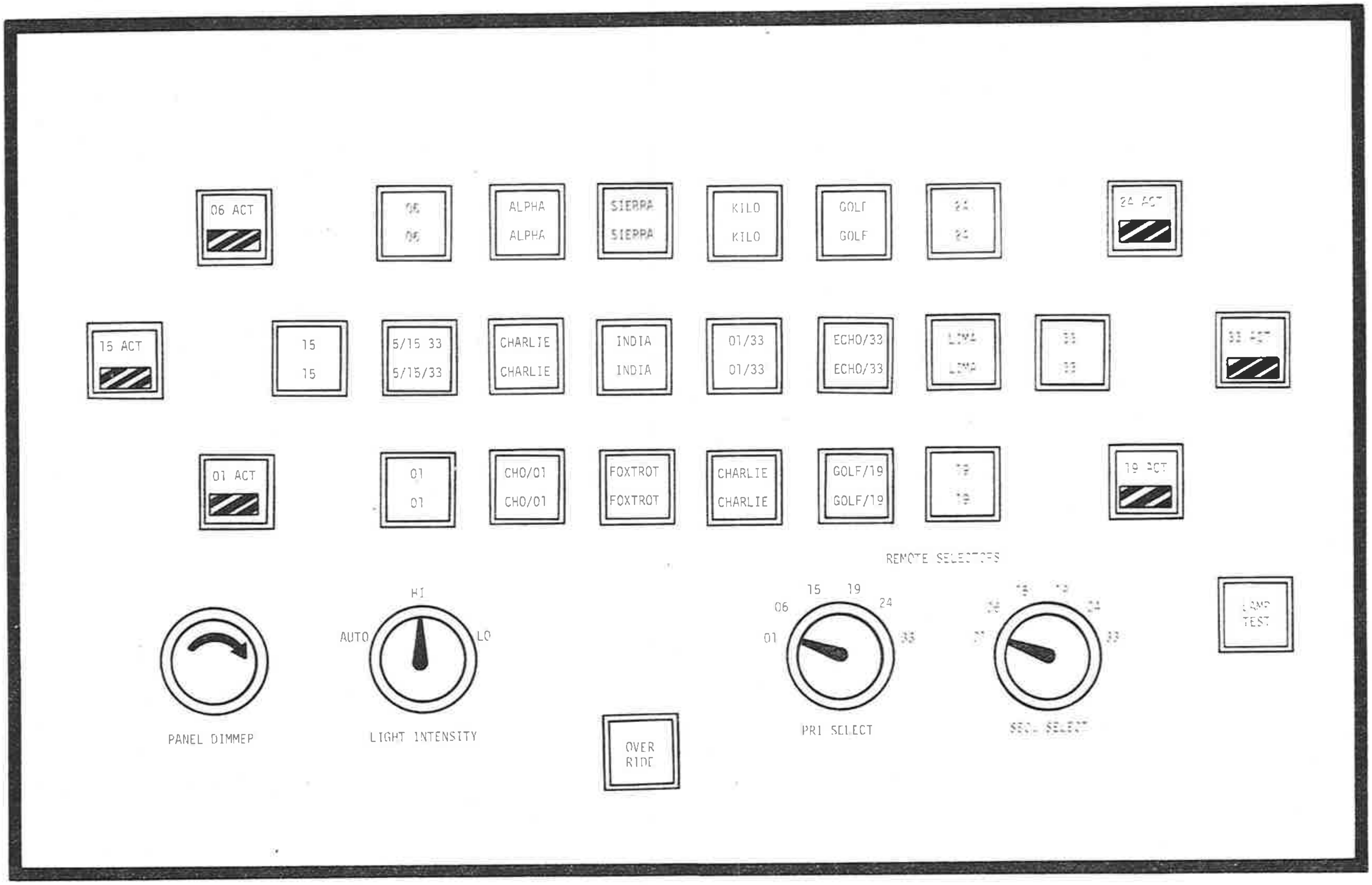

FIGURE 6-2. NAFEC KEYBOARD DISPLAY DESIGN

b. The display should be as small as possible; i.e., it should not take up too much space in the tower. However, small size must be considered against the ability of the controller easily to recognize the displayed function and manipulate all controls that form part of the display.

c. The display must be located so that it is easily viewed by the local controller. It must not be necessary for the local controller to leave his station or overextend his normal viewing position to see the display or operate any of the controls on the display. He also must not be distracted from his normal duties.

d. The display must not be complex or confusing to the local controller. Careful consideration must be given to location and spacing of the lights and switches so that the proper control light can be easily identified with the control point and the controller cannot inadvertently trip a wrong switch.

e. The local controller must be able to operate the controls from his position. If possible, one should be able to operate the control if one moves around the tower. This would require remote control techniques.

f. Display must have failure mode function indicators.

g. The cost of the display/control panel would not be a major factor if it meets criteria (a) through (f). It must be kept in mind that equipment costs represent about 25 to 30 percent of the total system costs and that any display/control panel concept that may ease the burden or be more acceptable to the local controller will be worth additional expense.

The mimic and keyboard (matrix) panels will be used at Bradley airport and opinions solicited from the controllers. Even if both panels are acceptable at Bradley, a different display/control panel might be designed for larger airports. Bradley has 21 light positions and uses only two runways most of the time. Some larger, more complex airports could require 33 or more light positions and have up to five runways. If the mimic or matrix panel design is considered for these airports, the overall size could be considerably larger for the same switch/light spacing as the panel to be used at Bradley, and there may be problems fitting such devices into the controller station. The size of the Bradley mimic panel is 13.2 x 14.3 inches while the keyboard panel is 8 x 14.6 inches. Spacing between switches on the matrix panel is 1/4 inch. To reduce this spacing further would impair the controller's ability to use the panel efficiently and safely. Discussions with FAA field personnel indicate that space in the tower to add new equipment is very tight and some suggest that all airport lighting be controlled from the same control display panel. For such reasons, the FAA requested that this alternative study investigate other display concepts and technologies. A survey was conducted to investigate the state of the art of various prominent display technologies and determine those having the best potential for VICON applications at larger airports than Bradley. The findings are discussed in the remainder of this section.

6.1 CATHODE RAY TUBE DISPLAY

The cathode ray tube (CRT) has found widespread use as a display device in both the tower cab and aircraft cockpit. It is constantly being improved to maintain its present competitive edge over the emerging solid state display and gas discharge (plasma) display technologies. Improvements have been made in brightness, luminous efficiency, overall size (especially depth), and longer life, through advancement in material technologies relating to phosphors, cathodes, and electron guns. Wide angle (greater than 90°) deflection tubes are readily available and have reduced the depth profile considerably. However, the most important reason that the cathode ray tube is the most dominant display device today is its amenability to matrix addressing which still poses some problems for other display technologies. In spite of advancements, cathode ray tube displays are constantly challenged by other display technologies for most display applications. Solid state and plasma gas discharge devices show not only promise of eventually being smaller, lighter, and more reliable than cathode ray tube displays, but also being cheaper and having higher performance. Research and other development work in these and other display technologies are going on at a rapid pace for both military and commercial applications and their present status will be discussed in the next several subsections.

Cathode ray tubes have been used in tower cabs for many years. They can be obtained in many sizes, both with and without graphic capability. Touch-entry panel or keyboard addressing is available. For VICON, a map of the airport surface depicting all, or only a section of the takeoff locations can be displayed. The operation of the VICON lights, or signs eventually selected, can be implemented by the local controller by touch, using his finger or an instrument opaque to infrared. The cathode ray tube display can be in color which can enhance its functional capability for many applications. CRTs are prime candidates for a VICON display at the more complex airports. Their only serious contender at this time is the plasma gas discharge panel display and the final selection of one over the other will depend primarily on space availability in the tower cab. The flat panel gas discharge display will be discussed in the next section.

6.2 PLASMA FLAT PANEL DISPLAY

The display technology most competitive to that of the cathode ray tube is the gas discharge flat panel plasma display, which has developed very rapidly and is now used in many applications once dominated by cathode ray tubes. Like the cathode ray tube, it can be considered a very strong candidate for a VICON display for an airport with many departure locations. Improvements in such important characteristics as brightness, luminous efficiency, contrast ratio, and matrix addressing have made the plasma flat panel display competitive with the cathode ray tube for many applications. The military have purchased a number of systems using plasma displays for use in aircraft and ground terminals due to their rugged construction as well as their size, weight and volume advantages over cathode ray tubes. The flat panel plasma display has other advantages over cathode ray tubes which are listed below:

1) Lower voltage operation (200 volts AC as compared to thousands of volts for a CRT).

2) Potentially higher reliability, and less and easier maintenance.

3) The aspect ratio (width to depth) of the flat panel plasma display is a desirable advantage over CRTs. It is a better than 2 to 1 improvement over state-of-the-art CRTs used in similar applications. The display can be hung on a controller's console and is easier to fit into a tower cab than a cathode ray tube.

The flat panel plasma display is now widely used in data-terminal displays. As the discrete electrode drivers of earlier panels were replaced by the microprocessor and other integrated circuits (large scale integrated circuit technology) the cost of plasma panel terminals became comparable to costs of CRT terminals. As production rates increase and component yields improve, the cost of plasma panels will eventually become less than the costs of CRTs, because CRT technology has already matured and costs have stabilized.

It is informative to consider here all computer-display requirements that a terminal must meet. The computer display requirements are selected as the example since, for VICON and other avionic applications, these displays would be used with microprocessors.

The requirements that must be met by any display technology used for the computer terminals are:

a) Generate and display all alphanumeric characters and a complete set of vector graphics.

b) Decode and implement the complete American Standard Code for Information Interface Character and Control set.

c) Contain an input/output interface compatible with Electronic Industries Association Standard RS-232C.

d) Accept and respond to operational inputs for interactive operation.

e) Display a minimum of 512 viewable characters for compatibility with page-oriented messages.

f) Provide programs for operating and diagnostic purposes.

There are both ac and dc plasma display panels. The first commercial versions were delivered in 1971. The ac panel appears to be the most promising due to its inherent memory and resolution.[7] The ac panel (Figure 6-3) consists of two glass sheets with deposited or etched electrodes. A dielectric glass layer coated with magnesium oxide covers the electrodes. A precision glass seal keeps the glass layers parallel and retains a mixture of neon and a small amount of zenon or argon at pressures ranging from about 400 torr to 760 torr.

The panels are fabricated with a 512 x 512 electrode matrix configuration. This means there are 512 x 512, or 262,144 addressable locations. The matrix requires 1,024 electrode drives operating at about 100 volts. The continuous ac voltage needed to sustain the image is less than the ignition voltage. When an address voltage pulse is applied between intersecting points and summed with the sustaining voltage, the gas between them is ionized, the plasma glows and an equal and opposite charge is stored in the dielectric layers.

The glow can be erased by applying an out-of-phase ac address voltage that momentarily reduces the sustaining voltage levels and cancels the stored charge. A 50 kHz sustaining frequency provides a 20 μsec writing rate.

The latest plasma panel terminals contain a display processor with a microcontroller supplying X- and Y-axis position addresses to the display and control circuitry which decodes them for the electrode drivers. The processor generates ASCII characters and graphic vectors. It can accommodate parallel input devices such as keyboards, joysticks, touch panels, and function switches. An interesting feature of the plasma panel is that since the plasma

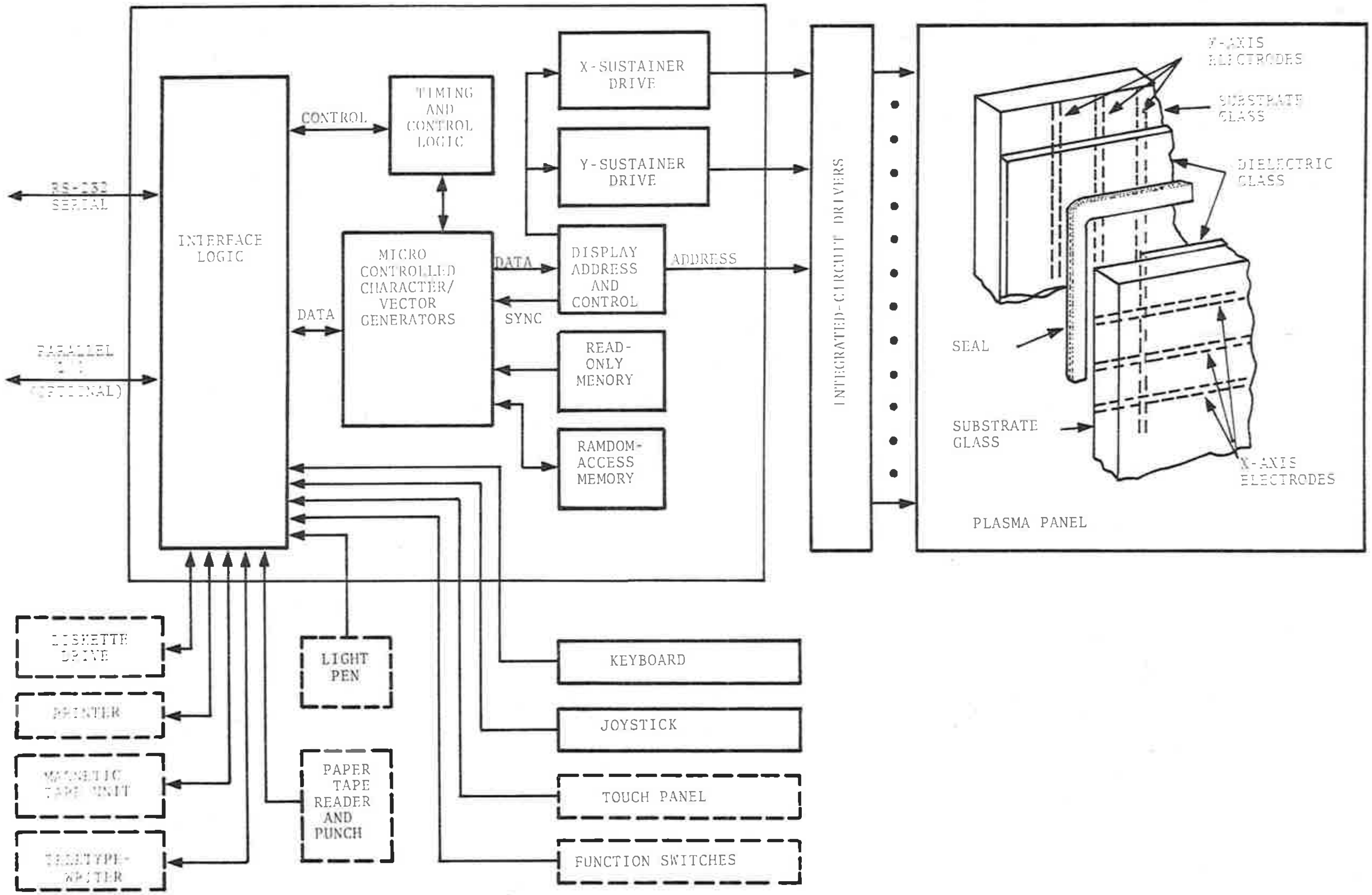

FIGURE 6-3. GAS DISCHARGE PLASMA DISPLAY

is transparent, images can be projected from the rear so that updated real time data can be superimposed on the image to dramatize the presentation. This could be used in VICON, for example, to project a surface map of the airport on the screen and then control the visual signal by superimposing, through touch panel means, the location of the light that should be controlled.

The plasma display has excellent high speed graphics capability. An optional touch panel can be installed on the faceplate allowing an operator a selection of 256 touch positions. Some companies which design systems incorporating these displays are listed in Appendix B.

6.3 OTHER DISPLAY TECHNOLOGIES

There are other display technologies that are used in various commercial, industrial, and military applications which either are not suitable for VICON or are not sufficiently developed at the present time to be seriously considered for VICON. These are listed below:

1) Non-Emissive Displays (Liquid Crystal and Electrophetic Technology)
2) Matrix Displays (LEDs, Thin Film Transistor and Electroluminescent Thin Films)
3) Projection Displays.

The non-emissive devices, principally liquid crystal, provide a black and white display and are being widely used in commercial applications. Since they are passive devices depending on reflective light for activation, they have not been used much in avionic applications; indeed, there are other display technologies including cathode ray tube and plasma discharge which have many advantages over liquid crystals for avionic applications. Matrix addressing of liquid crystal displays is still being developed. Electrophoretic displays have high contrast and wide angle viewability and are being worked on in the laboratory at the present time. They are not considered a candidate for VICON at this time.

Matrix displays are used for a variety of applications. Light Emitting Diodes (LEDS) are used in products such as watches, and cockpit instruments in airplanes (digital readout devices, heads-up displays). Compared to cathode ray tube and plasma displays, they have problems such as "wash out" in high ambient light and are not being considered for VICON at this time. Thin film transistor and electroluminescent thin film matrix displays are only laboratory models at the present time.

Projection displays also suffer from insufficient contrast brightness ratios under the severe ambient light conditions encountered in the tower cab and are not a viable VICON display candidate at this time.

6.4 SUMMARY

A system consisting of a touch entry flat panel display (plasma discharge or cathode ray tube), a microprocessor controller, multiple display buffers and interfaces to control VICON lights or a message sign is suggested for use at airports where there are a large number of takeoff locations and/or runways. This is because as the number of takeoff locations increases, the panel (mimic and/or keyboard) must increase in size to accommodate the larger number of switches and lights required to operate the VICON lights or message signs. At a large airport, the mimic and/or keyboard panel could thus become too large and cumbersome for the controller to operate effectively and could present problems with trying to fit it into the tower cab. A touch-entry display, on the other hand, could be offset or paged to present only the take-off locations of interest to a particular local controller for a given runway configuration, while maintaining a reasonable overall display size. The display system shown in Figure 6-4 can easily interface with a solid state relay simulator control device planned to replace the relay panels which are being used at Bradley Airport for the operational field tests. This will make the system almost completely solid state, the hardware configuration being requested by AAF for the VICON system if the Bradley tests result in a decision to install VICON

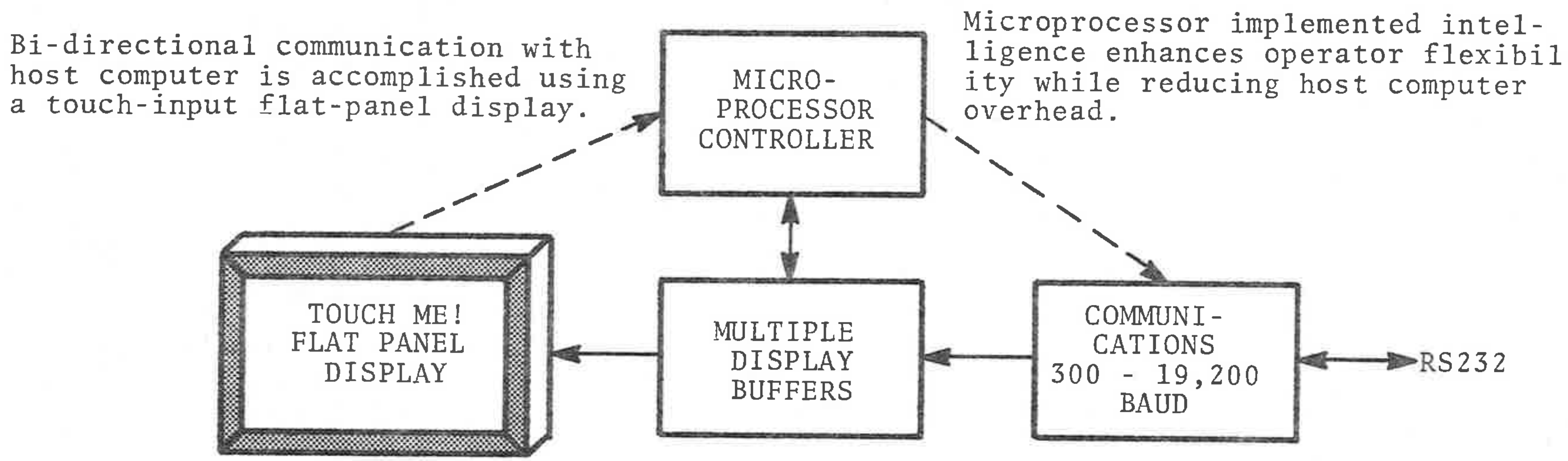

FIGURE 6-4. FLAT PANEL MICROPROCESSOR CONTROLLER DESIGN

at all FAA towered airports in the United States.

The system shown in Figure 6-4 would be operated by the local controller who merely touches a specific position on the display panel to activate a specific VICON light or message sign and, at the same time, place the message or light on the display. The exact location, with identification of runway or runway/taxiway intersection, could be made to appear alongside the light, or as part of the message, on the display. The local controller, upon touching the display panel in a specific location, can display the page from a multiple page memory, which shows the runway one is working with and the light one activates either on the runway or a taxiway/runway intersection. A local controller can also localize, on the display, only the area one is interested in using, i.e., "blown up" sections of the airport. If a cathode ray tube display is used with graphic capability, a map of the region of the airport surface being worked with can be drawn on the face of the cathode ray tube and the appropriate departure locations touched to activate the visual signal on the airport surface corresponding to the desired location. If a plasma discharge panel, which has an orange-amber color, is the display, a map showing the runways and taxiways of the airport surface can be projected on the face of the display and the departure locations can be touched, as on the cathode ray tube, to activate the VICON light.

Systems using displays of these types and microprocessor controllers have considerable versatility and capability to perform a wide variety of functions in addition to VICON. They cost about 4000 to 5000 dollars. The dimensions of a typical system containing the display and microprocessor controller, such as shown in Figure 6-4, are as follows:

1) Display is 12 x 9 x 2 3/4 inches deep and weighs about 12 pounds.
2) The microprocessor controller is 12 x 8 x 6 1/2 inches deep and weighs 12 pounds.

3) The microprocessor controller and display are separable up to 10 feet. Therefore, the display, which can be a flat panel plasma discharge type, can be attached to the local controller station at a desirable location, while the microprocessor controller can be located on the floor in back of the station or at some other convenient location. This is possible because of the "touch me" enable feature of the display.

7. SIMPLE VICON MODIFICATIONS

7.1 MODIFICATIONS OF CURRENT VICON DESIGN

Assuming that the VICON system design to be operationally tested at Bradley meets with approval of controllers and pilots, it is interesting to consider some modifications to the system which can be tried with little increase in funds but which can enhance the overall performance and efficiency of the present VICON system.

If the control/display panel and pulsating light are acceptable, the equipment which is used to power and control the system can be upgraded to provide an even more reliable, maintenance-free system. This can be accomplished by using a solid state microprocessor controller which will replace numerous relays, reduce size and costs of facilities needed to shelter the relays, and be more maintenance-free. In fact, NAFEC engineers have initiated a procurement for such a solid state controller called Director 3001,® manufactured by Struthers-Dunn, Inc., a relay control company.[8]

The Director 3001 Controller requires less than 3 1/2 square feet of installation area. (Compare this with the 6 1/2 foot by 12 foot wall-mounted unistrut installation at Bradley.) The Director 3001 Controller actually is 28 1/2 inches high and 17 1/2 inches wide. Essentially, it is part of a microprocessor which has 128 inputs/outputs. All inputs/outputs are easily accessible at the front end of the Director 3001.

A total of 120 internal storage locations (simulated relay coils) are available in the Director controller, in addition to unused input and output addresses which can also be used in storage locations. It is self-protecting with a built-in fault monitoring system which automatically monitors for various faults.

The Director 3001 can use up to 3,000 positions of user program memory and contains ultraviolet-light-erasable Read Only Memory. Optional data handling software can be added to enhance its functional capabilities.

The controller can be programmed in relay ladder format, monitored, and modified using a program loader also supplied by Struthers-Dunn. For production quantities, which would be needed if the system were to be installed at every towered airport in the United States, it would be more economical to submit each control circuit design for each individual airport to the manufacturer to program. Since each airport requires different locations for the system lights, a uniform ROM card cannot be designed.

The cost of a controller such as the Director 3001® is expected to be 3000 to 5000 dollars. The program loader costs approximately 2000 dollars.

7.2 TAKEOFF CLEARANCE PROCEDURAL CHANGE

In considering alternative schemes to provide a confirmation of voice takeoff clearance signal, emphasis has been placed on using a different stimulus, namely vision. However, it has been apparent to those involved in the VICON program and from responses to a recent TSC controller survey that perhaps the simplest, and certainly least costly, way to confirm the controller takeoff clearance instruction is to require the pilot to acknowledge that he is cleared for takeoff by a mandatory verbatim repeat of the instruction issued by the controller. At the present time the pilot generally acknowledges the cleared for take-off instructions by some abbreviated message such as "World Wide 123 cleared," or in some cases, where the communication channels are loaded, not at all. A verbatim repeat of the complete controller take-off clearance instructions by the pilot would verify his proper receipt of the exact message and eliminate any misunderstanding or confusion because the reply message was shortened or nonexistent. Although this would require additional time, increase voice communication channel usage and pilot and controller workload, it would eliminate lights, power, etc. which are costly to install and operate in an airport.

Another procedural standard which should be assured in the future is the strict separation of the en route ATC clearance and the take-off clearance. Confusion of the en route ATC clearance with a combined ATC departure clearance was a major contributing factor in the Tenerife accident. This confusion is more probable at the smaller airports where a single controller handles the clearance delivery, ground and local control functions.

8. AUTOMATIC SIGNAL TURN-OFF SENSORS

An important VICON requirement is to impose minimal additional workload on the controller caused by the extra function of operating the VICON system. The controller is required to "turn on" the green VICON light to confirm his voice takeoff clearance instruction, and it should not be necessary to deactivate or "turn off" the VICON light manually once the plane has departed. At Bradley International Airport the light will be "turned off" automatically, using microwave sensors located at four runway ends and timers at all other runway/taxiway intersection takeoff locations.

There are a number of automatic detectors that have been used for highway traffic detection and control applications. An attempt has been made to use some of these to detect and control aircraft at airports and they have proven ineffective or unreliable. A list of some detector units is given below:

1) Induction loop detectors

2) Magnetometers

3) Magnetic detectors

4) Radar detectors

5) Sonic detectors

6) Treadles.

Although loop detectors have been effective for automotive applications they have not been reliable enough for aircraft detection. An induction loop system, used at NAFEC during the NAFEC VICON tests, was found inadequate for use at Bradley Airport.

Based on preliminary tests made at NAFEC, it was decided to install a microwave radar detector system, at Bradley, with sensors located 1000 feet from the ends of runways 6, 24, 15, and 33, to turn off the VICON lights automatically once the aircraft interrupted the transmitted signal. The placement of the detectors along the runway is critical since it is intended to "turn off" the lights for both heavy and light aircraft. The Bradley tests should determine an optimum location for placement of the sensors for all aircraft classes.

The microwave radar detector operates at 10.55 GHz. The transmitter and receiver are placed on opposite sides of the runway, approximately 100 ft from the edges of the runway. A problem may occur in heavy snowfalls where snow piles can be high enough to "block out" the microwave signal. To eliminate this problem, back up timers may be used under conditions where microwave system cannot.

For takeoffs from runway/taxiway intersections, a timer will be used automatically to "turn off" the VICON lights. The required timer setting will be determined from the Bradley tests. Initially, the timer will be set for approximately 30 seconds from when the light is turned on.

No detector, other than those previously mentioned, was found that has proved effective for aircraft detection. Even the microwave radar has yet to be proved. The Minnesota Mining and Manufacturing Company has improved magnetometer and magnetic detector performance for automotive applications, but these have not yet been tested at airports.

9. OTHER VICON CONCEPTS

The argument for visual sources (lights, signs, etc.) is based on the assumption that an additional human sense (vision) can provide a more secure confirmation signal both psychologically and physically. On the other hand, if a confirmation visual signal source is placed on the airport surface, problems arise, similar to those encountered with present airport lighting systems. For example, bad weather such as fog, snow, etc., reduces the effectiveness of visual surface signals. In addition, the pilots must search for the signal, which may distract him from other important tasks one is performing. There are also maintenance considerations as well as the problem of the airport being already inundated with surface lighting. For these and other reasons it is worthwhile investigating other posible methods to provide a confirmation clearance to voice clearance signals for aircraft departures. In this section, techniques for putting the confirmation signal in the cockpit of the aircraft will be discussed as well as techniques using the existing lights as suggested by R. Gates of Gates Associates. (Airport Lighting Consultants.[9])

9.1 AIRCRAFT COCKPIT CONFIRMATION SIGNAL CONCEPTS

An alternative to the airport surface visual sensor confirmation signal concept is to provide a confirmation signal (visual or aural) to the pilot in the aircraft itself, requiring cockpit equipment. This would eliminate problems generally encountered when visual signals are placed on the airport surface. It also would eliminate the disruption caused at an airport when additional lights are installed. The principal argument against this concept is that additional aircraft equipment (possibly a light) will be needed in the cockpit, and that if this were true, the general aviation community would object unless equipment presently installed in their planes could be used. Since a confirmation signal system must be developed for all aircraft classes the concepts presented in this category may prove difficult to implement. However, there are methods that are worth considering if the airport surface visual signal source concept fails. The following discussion of such methods is not intended to be all inclusive. It is hoped that this discussion will foster ideas from readers of this report for other ways to put the confirmation signal in the cockpit of the aircraft.

9.2.1 DABS

DABS (Discrete Address Beacon System), if implemented as part of the Air Traffic Control System, may be an excellent vehicle for providing a confirmation clearance signal in the cockpit of an aircraft. The DABS data link has message bits available for triggering a visual signal or display in the cockpit to confirm the voice takeoff clearance.

The DABS transponder will be designed to perform the functions of two basic equipments, namely:

1) A conventional ATCRBS transponder

2) A regular DABS transponder with capability for All Call (ATCRBS and DABS only) Surveillance and COMM-A.

The DABS signal format will consist of a variety of message and identification bits along with some descriptive bits. It is not necessary here to describe the signal format in detail, but only to make one aware that the necessary channel space does exist in DABS uplink and downlink communications to provide a confirmation takeoff clearance signal to the pilot either visually or aurally. Figure 9-1 shows a DABS airborne system proposed by Bendix for other applications but applicable for a confirmation clearance signal function which, of course, would be only one of several functions performed by the system.[10]

The color CRT indicator, or a line printer, would display a message indicating the aircraft is "cleared for takeoff." This would backup the voice communications instruction. The interrogation equipment would be located in the tower. Figure 9-2 shows a keyboard control panel that could be used with the DABS system. DABS, however, requires further testing in an operational

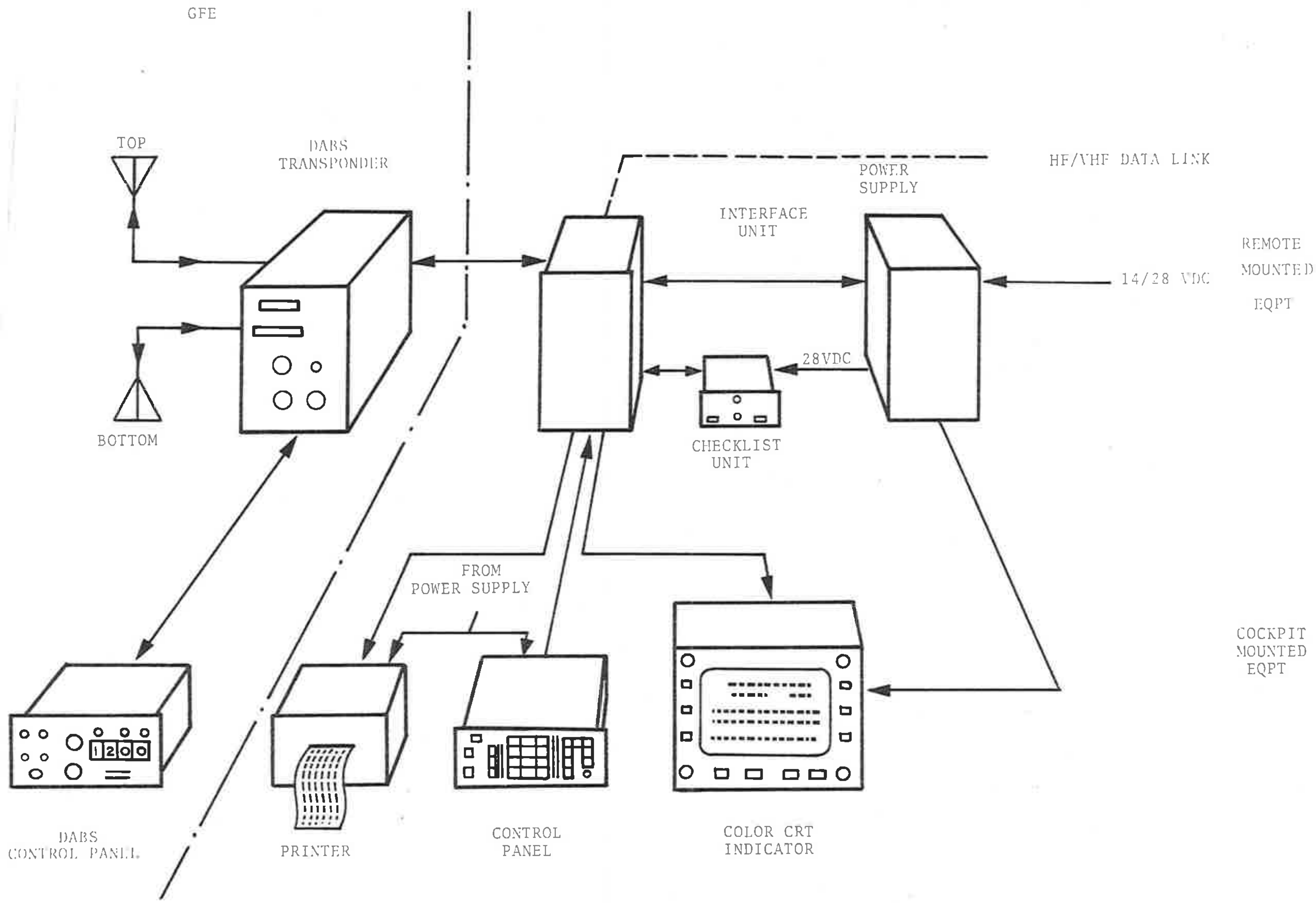

FIGURE 9-1. DABS EXPERIMENTAL AIRBORNE DATA TERMINAL

DEPTH 7.67"

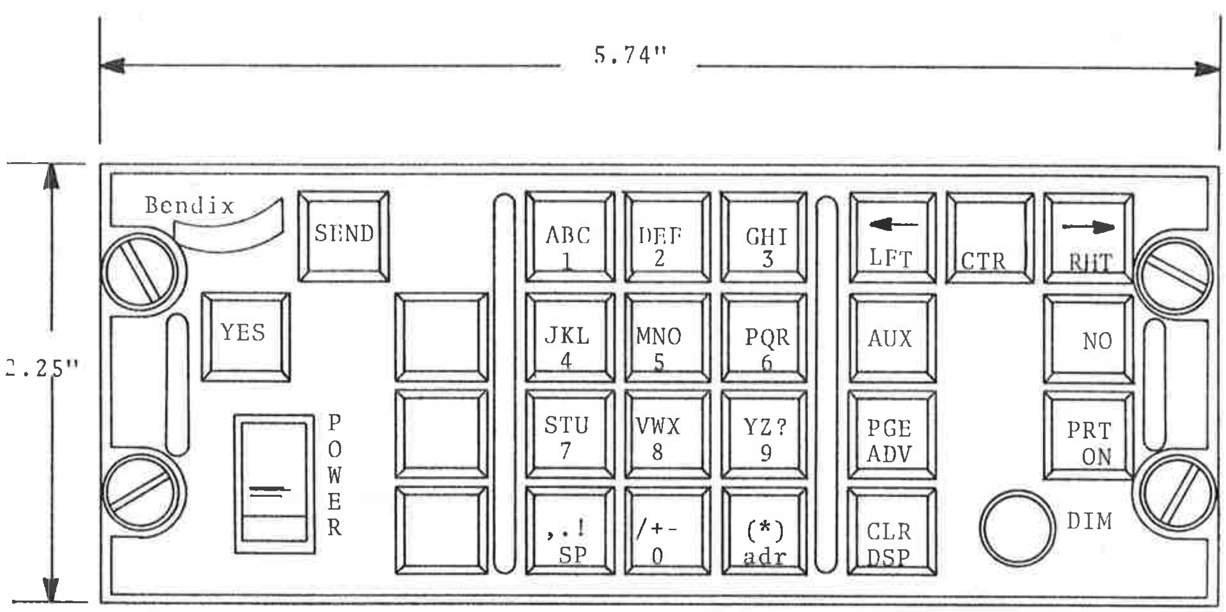

FIGURE 9-2. DABS CONTROL PANEL

environment to determine if it can function correctly on an airport surface. Tests with vehicles in queue, large planes blocking small planes, and planes behind obstructions blocking the signals, will have to be conducted before DABS can be used as a data link on the airport surface.

Until it is clearer when, and how universal, DABS deployment will be, it is uncertain as to how widespread a role DABS could play for confirmation of a voice takeoff clearance.

9.2.2 Voice Recognition Systems

Another conceptual alternative to the VICON signal system involves voice recognition systems.[11] Again these systems would be used to provide a backup clearance signal in the aircraft cockpit.

In a typical automatic speech-recognition system intended for isolated words and limited vocabulary, the incoming voice is spectrally analyzed. From the detected spectral shape and its rate of change, features that are characteristic of the basic sounds that comprise the spoken words are derived. When the end of an utterance is detected by what is known as the feature-extractor logic, the processor time normalizes the data so that dependence on word duration is minimized. Pattern-matching logic then compares the time-normalized feature set for the spoken word with stored reference patterns for each word in the vocabulary that was derived during the machine's "training." If the incoming word does not match any of the words in the vocabulary, a reject decision is made. All recognition and reject decisions are displayed back to the operator for visual verification. A typical system block diagram is shown in Figure 9-3.

Automatic speech recognition (ASR) systems are adaptive; that is, they require training for individual talkers and/or words. The system can be automatically "tuned" to the voice characteristics of any single user in a short time simply by having the user speak each desired word several times to provide a reference set of

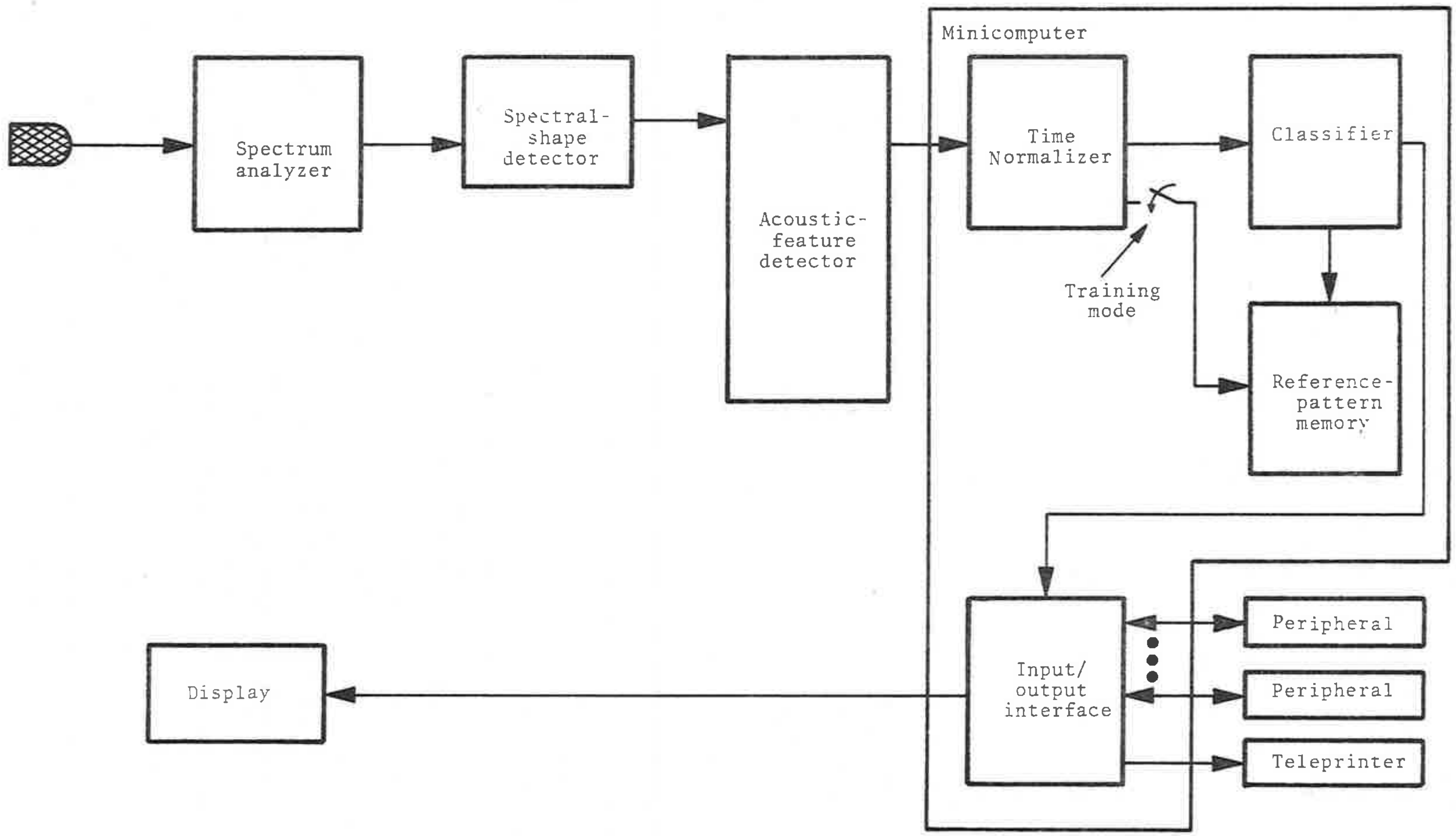

FIGURE 9-3. VOICE RECOGNITION SYSTEM

features. The system stores in its memory an individual reference set of words/features for each word in the vocabulary and for each talker in the system.

Commercially available isolated-word, limited-vocabulary speech recognition systems are only the first hierarchy of speech recognition. The more difficult task is producing connected-speech recognition systems with limited vocabulary. Such systems are presently being studied at IBM, Bell Laboratories, and Carnegie-Mellon Institute.

An area of application for such systems is, of course, air traffic control, where both instructions to pilots and updating of the Air-Traffic Control Center's computer can be simultaneously accomplished by the controller's voice signal. A voice response system is presently operating at the Transportation Systems Center in Cambridge.

It is also apparent that voice recognition systems can be a replacement for keyboards in computer terminals or wherever keyboards are used. The operator can then issue instructions to the machine (microcomputer or microprocessor) to carry out numerous tasks, including departure clearances and verification. This would eliminate the need to manipulate push button switches, etc. to operate a departure clearance confirmation signal system. It must be recognized though that Voice Recognition and Entry systems are still under development and are not State-of-the-Art at the present time.

10. VICON INSTALLATION AND OPERATION ANALYSIS

The following discussion will deal with a VICON installation and operational analysis chart submitted to TSC by R. Gates of Gates Associates. This chart, shown in Table 10-1, lists techniques for providing a voice backup signal for aircraft departures using existing visual signals. The approach is similar to the present VICON signal concept but takes advantage of lights presently existing on runways and taxiways and the use of red signals to provide a confirmation visual "backup" signal to voice clearance. The chart shows the VICON signal recommended for five different conditions of runway use and operational procedures. Note the use of red stop-bars on the taxiway. The optimum system configuration would use "in pavement" lights although it is stated, "other locations along the runway and taxiway side might be used." It is cautioned though that lights along taxiways and runways might be inadequate in low visibility operations. In addition to the red stop-bars, the system would use existing in-pavement lights on the taxiway and runway to provide the visual "backup" clearance signal with minor modifications, or add some centerline lights where required.

It is noted that the use of the signals listed in this scheme by R. Gates is considered to be a "controller's tool;" that is, they need not be operated at all times or are they required to be installed at all airports. This is due to the inclusion of both stop and go signals. A similar design was proposed by TSC when VICON was first discussed. That system, also, would use stop and go signals, either "in pavement" or along the sides of taxiways and runways or a combination of both.

Table 10-1 lists various VICON signal sources to meet various operational conditions for aircraft departures. It does not discuss methods for controlling the visual signals or verifying their status to the controllers. It is assumed that techniques applicable to the present VICON design concept to be implemented at Bradley would be used for control and display purposes in the tower.

TABLE 10-1. VICON INSTALLATION AND OPERATION ANALYSIS

RUNWAY	DEPARTING AIRCRAFT POSITION*	ATC INSTRUCTION OR CLEARANCE	VICON SIGNAL	COMMENTS
A. Departures only- no crossing traffic	At holding line	Cleared for take-off, or instructed into position and hold	None required.	Any operating error would not result in an accident
B. Arrivals & departures or crossing traffic	Approaching holding line	Taxi to runway, hold short of runway.	Red stop-bar, no taxi centerline lights between stop-bar & runway.	Red stop-bar located so that cockpit would be positioned at holding time.
C. (Same as B.) however, no aircraft on runway, or aircraft crossing runway.	At holding line on taxiway.	Cleared for take-off.	Red stop bar off: taxiway centerline lights between stop-bar and runway edge energized for about 10 sec.	Since green centerline lights are directly ahead, about 10 sec. on-time should be adequate for pilots to observe signal and start rolling. (Red stop-bar also would be off for same time period and re-energized so as to stop next aircraft in line for departure)
D. (Same as B.) however, a landing aircraft is rolling-out or an aircraft is crossing the runway.	At holding line on taxiway.	Instructed to take position on runway and hold.	(Same as C. above) in addition, white runway centerline lights switched to red for first 500' of runway.	Either centerline lights are rotated 180 degrees or separate fixtures installed adjacent to existing fixutres.
E. (Same as B.) with no aircraft on runway or aircraft crossing runway.	Holding on runway awaiting take-off clearance.	Cleared for take-off.	Red centerline lights switched back to white.	Use of standard white color eliminates need for further switching.

NOTE: The above analysis shows the need for two separate signals to be installed and operated, provided current ATC procedures are used to instruct aircraft to take position and hold on the runway. It is assumed that at busy airports, this procedure is needed to expedite departures and would justify the additional installations on the runway and the requirement for switching. Low traffic density airports could operate with the stop and go signals only on the taxiway, as in c. above.

It is evident that the above signals are optimum in design. Other locations, such as along the taxiway and runway side might be used, but in low visibility operations they may not prove adequate.

It is also evident that the above signals permit their use as a "controllers tool" - they need not be operated at all times - neither are they required to be installed at all airports. This is due to the inclusion of both stop and go signals. Pilots would know that where they are not stopped by red signals, current voice-only communication procedures are in effect. The signals do not replace voice communications; visual signals are voice back-up only.

As mentioned earlier, the VICON concept shown in the chart is very similar to the present VICON system design concept. If the tests at Bradley indicate that the present visual signal sensor is inadequate, the concepts listed in the chart by R. Gates will be thoroughly reviewed for consideration as an alternative.

11. CONCLUSIONS AND RECOMMENDATIONS

A number of alternatives to the VICON system design concept which have been tested at the Bradley International Airport beginning in August 1979 have been discussed. It is not intended to imply here that these are the only alternatives that are available to perform the takeoff clearance confirmation function. Rather, additional ideas may be stimulated from those concerned with developing a confirmation of the voice takeoff clearance signal system.

It would be premature to propose a "best alternative approach" until the results of the Bradley field tests on the present VICON design concept are known. Basically, the choices available are

1) Modification of the existing VICON system, and

2) Development of a new takeoff clearance confirmation system.

It is difficult to conceive a simpler system using a visual signal than the one being tested at Bradley Airport. A pulsating light displaying only a single color, green, a control/display panel in the tower, and power and control interfaces comprise the system.

This report has concentrated on the light signal and control/display panel since these are the two key components. The intention has been to find substitutes that can make the tasks of operating and using the system by the controllers and pilots easier in the event the Bradley VICON system is found unsuitable for installation at all towered airports.

The controller task can be made easier only through automation or by establishing another control position whose function would be to assist the local controller by operating the control/display panel. The touch-entry displays which were described earlier could alleviate problems associated with fitting the VICON control/display panel in the tower cab and might reduce the probability of an undetected control error, but they would probably not result in a significant reduction in controller workload.

It appears that if the establishment of another control position were out of the question, the best choice to make the controller's task easier would be a voice actuated automated system (voice recognition) which requires considerable development (5-10 years). The controller issuing the confirmation of a voice takeoff clearance signal would not have to push any switches but would use his voice to actuate a visual confirmation signal either on the airport surface or in the cockpit of an aircraft. However, voice recognition systems exhibit difficulty in recognizing different voices at this time. This problem will have to be solved before a confirmation of voice takeoff clearance system using this principle could be developed. Recent advances made in VLSI (Very Large Scale Integrated Circuits), such as silicon semiconductor chips containing approximately one-quarter of a million transistors, are expected to enable increases in levels of speech recognition possible with current technology.

The next most attractive approach for providing a confirmation of voice takeoff clearance would be the use of the DABS data link if DABS operates satisfactorily on an airport surface. This approach would eliminate the need to put more signal lights on the surface and thus alleviate weather and maintenance problems associated with airport surface lighting.

Recent plans call for a Test and Evaluation (T&E) of DABS at NAFEC in 1980 and/or 1981. However, it is most likely that the utilization of DABS in air traffic control is still some years away and would not provide an immediate, usable confirmation of a voice takeoff clearance system. Nevertheless, the takeoff clearance confirmation function has been given a high service priority, based on safety of operation in a TSC-FAA report.[12] Since the T&E of DABS at NAFEC is still in the planning stages, it is recommended that coordination be established between the FAA Data Link Program Office and FAA Systems Research and Development Service to discuss the possibility of incorporating the takeoff clearance confirmation function in the DABS NAFEC tests.

If the tests of the current VICON system at Bradley are successful and the system is acceptable in part or whole to the controllers and pilots, it is recommended that the next step be the replacement of the relay control unit apparatus by the microprocessor-based Director 3001® control unit. It is assumed that the control/display unit and visual sensor are acceptable in their present design form. This modification will result in decreased equipment and installation costs since on some towered airports it may be necessary to build a 12 foot x 12 foot shelter to house the large relay rack structure used in the present system. The entire Director 3001 controller occupies less than 3 1/2 square feet, installed. The Director 3001 would only replace relay devices in this application. The versatility of the microprocessor controller can be increased through optional data handling software. The cost of a unit of this type would be approximately 2000 dollars. Since this type of controller uses a Light Erasable Read Only Memory (LEROM), it can be programmed using a program loader and is erasable with ultra-violet light. A program loader can be purchased on a one time basis for approximately 3000 dollars and used to program the Director 3001 Controller for each specific towered airport VICON installation.

To make the controller's task of operating a VICON system easier, it is necessary to automate as much of the control function as possible. The actual depressing of switches on a display/control panel by the local controller may be too distracting since among other reasons controllers are often fearful of depressing the wrong switch. On the other hand, the controller must maintain complete control of takeoff clearance under present procedures. A system using a touch-entry type plasma display, or a touch-entry cathode ray tube display, may be easier to operate as well as to read by the controller. Two types of touch-entry panels, the infrared "electric eye" and the touch-wire, which senses through contact between conductors, are available. The use of more sophisticated displays for this application is justifiable for larger airports where a large number of takeoff positions must be controlled. In such cases, a tradeoff must be made on the basis of space availability in the tower for CRTS, plasma displays and the current display/control panel devices. It is possible also to separate the control panel from the display panel physically, using a keyboard control which could be mounted on the controller's control console, the display being suspended above the console. In any event, as long as the controller is faced with the prospect of depressing switches on the current NAFEC-designed control/display panels or CRT plasma touch-entry or keyboard entry type, one encounters the same problems regarding distraction, probability of mistakes related to depressing switches, and additional work. To avoid this the only solution would be a voice actuated system that initiates an electronic control signal, or provision of a dedicated control position.

The use of message signs rather than lights is recommended only if the present visual sensor (or any type light) to be tested at Bradley is unacceptable to pilots. The actual displaying of the message leaves little room for misinterpretation of the function for the viewer. Other types of information can be conveyed to insure that the takeoff clearance confirmation signal is directed to the proper aircraft. The cost of a message type system is approximately 30,000 dollars per departure location.

Optically programmed signals have been used successfully in controlling difficult and complex highway traffic intersections. They may perform a similar function as a visual sensor in VICON. It is recommended that this type of light signal be tested to determine if it provides an additional safety feature to the VICON system.

The use of existing runway lighting, as outlined in Table 10-1, appears to be rather confusing and complex. It suggests the use of red stop-bars in addition to centerline lighting to control aircraft and confirm the voice takeoff clearance. This would require installing additional lights in the pavement which is very costly. The use of a red signal implies control rather than confirmation. The use of existing lighting to provide another function may prove confusing to the pilot who has been indoctrinated to accept the original function of such lighting. Perhaps the use of the red stop-bar along with existing lighting would be more applicable to another problem, runway intrusion.

Some of the concepts discussed in the text are more acceptable if they can also be used in other problem areas such as runway intrusion, in addition to providing a confirmation of voice takeoff clearance. The development of microprocessor controlled systems with sophisticated displays can more easily be justified from the cost viewpoint if more than the confirmation of voice takeoff clearance function is obtained.

Finally, if a procedural change in current issuing of voice takeoff clearance instructions were made so that the recipient of the voice takeoff clearance instruction had to repeat the controller's takeoff clearance message verbatim, it could be a step in the proper direction to prevent the occurrence of another Tenerife type accident. It would certainly eliminate the need for installing an additional system to the already large arsenal of systems slated for airports in the future and save considerable money and valuable tower space.

12. REFERENCES

1. Article on Safety; Spaniards Analyze Tenerife Accident, Aviation Week and Space Technology, Pages 113-121, November 20, 1978.

2. Article on Safety; Clearances Cited in Tenerife Collision, Aviation Week and Space Technology, Pages 67-74, November 27, 1978.

3. Yatsko, R.S.; Mackenzie, F.; Coonan, J.R.; Preliminary Cost Estimate of a Visual Confirmation of Voice Takeoff Clearance (VTVC) Signal System Installation at Bradley International Airport, Material on File at DOT-TSC, December, 1977.

4. Visual Confirmation of Voice Takeoff Clearance (VICON) Operational Test Plan, NAFEC, March 1979.

5. Evaluation of an Airport Traffic Signal System Concept, Final Report, FAA-RD/67-30, NAFEC, 1967.

6. Brooks, W.; Message Displays: Some Design Considerations, Technical Note 1, NAFEC, October 1973.

7. Sobel, A.; Gas Discharge Displays: The State of the Art, Proceedings of the Society for Information Display (SID), Vol. 18, No. 1, First Quarter, 1977.

8. Private Communication, A. Novakoff.

9. Private Communication, R. Gates.

10. General Purpose Experimental Airborne Data Terminal, Bendix Avionics Division, Working Paper, March 1978.

11. Martin, T.B.; One Way to Talk to Computers, Spectrum, Vol. Pages 35-39, May 1977.

12. Canniff, J.; Golab, J.; Functional Utilization of DABS Data Link Discrete Address Beacon System, Final Report, DOT-TSC, FAA-RD/78-159, October 1978.

APPENDIX A

CURRENT PROGRAMMABLE MESSAGE SIGN MANUFACTURERS

American Sign and Indicator Corporation
North 2310 Francher Way
Spokane, Washington 99206

Crouse-Hinds Company
Syracuse, New York 13201

Dietz Company
225 Wilkinson St.
Syracuse, New York 13201

Display Technology Corporation (DISTEC)
160 Main Street
Los Altos, California 94022

Federal Sign
Division Federal Signal Corporation
5018 Chase St.
Downers Grove, Illinois 60515

Ferranti-Packard, Ltd.
Electronics Division
121 Industry Street
Toronto, Ontario M6M 4M3
Canada

Flishback & Moore, Inc.
Heath Company
4703 Bengal Street
Dallas, Texas 75235

FOSCO Fabricators, Inc.
P. O. Box 200
Dixon, Illinois 61021

Information Concepts, Inc.
592 Fifth Ave.
New York, New York 10036

Rank Precision Industries, Inc.
Leeds LTD, England

Radar Safety Controls Company, Inc.
20 Republic Road
North Billerica, MA 01862

Rhode & Maine, Inc.
824 D. East Walnut Ave.
Fullerton, California 92631

Solari America, Inc.
45 West 45th Street
New York, New York 10036

Varicon 3M
Traffic Control Products Division
3M Center
St. Paul, Minnesota 55101

Winkomatic Signal Company
659 Miller Road
P. O. Box 155
Avon Lake, Ohio 44012

APPENDIX B

DISPLAY/CONTROL PANEL MANUFACTURERS

General Digital Corporation
700 Burnside Ave.
East Hartford, Connecticut 06108

Interstate Electronics Corporation
707 E. Vermont Ave.
Anaheim, California 92803

SAI Technology Company
4060 Sorrento Valley Blvd.
San Diego, California 92121

Ramtek Corporation
585 North Mary Ave.
Sunnyvale, California 94086

DeAnza Systems, Inc.
3446 De La Cruz Blvd.
Santa Clara, California 95050

Grinnell Systems
2986 Scott Blvd.
Santa Clara, California 95050

Command Control Communications Corp.
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