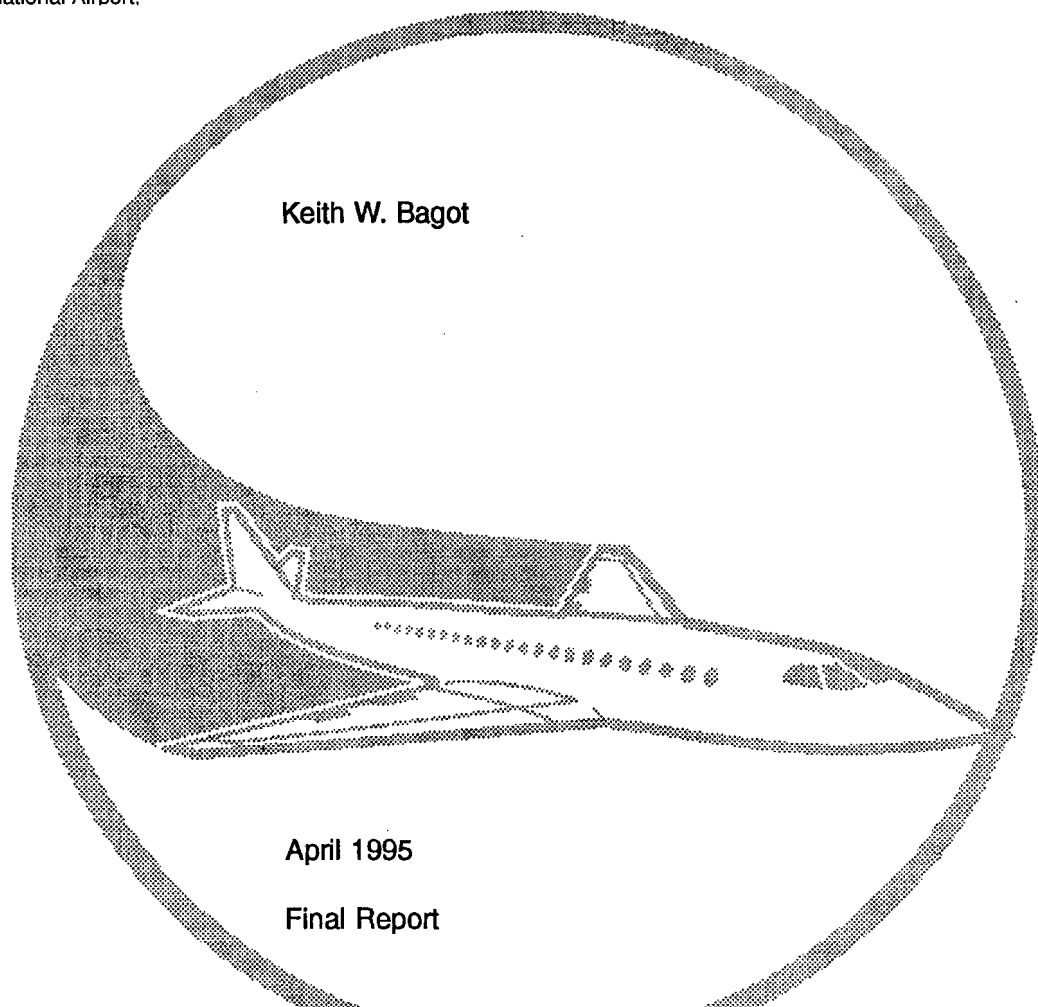


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Visual Guidance Automation Technology Assessment

Keith W. Bagot



April 1995

Final Report

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16. Abstract This report provides an assessment of current devices and technologies which may be applicable to the navigation and control of aircraft and service support vehicles on the airport surface traffic management area. The areas investigated included object sensing systems, object location and detection systems, visual aids, communication and control systems, and human factors facilities. The components, devices, or systems in each area were rated based on the maturity, applicability, compatibility, and risk as related to the FAA mission of airport surface control. A major finding of this assessment was that although there are many devices used in commercial vehicular traffic control systems and in industrial process control systems, the application of these devices to the FAA mission is restricted by the large signal range needed for object detection for airports in all types of weather and visibility conditions.					
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EXECUTIVE SUMMARY

A major element of the FAA mission is the safe and effective control of vehicles on the airport surface movement areas, which are the busiest of all the National Airspace System (NAS) control areas. The airport surface movement area includes all runways, taxiways, and holding areas. It is projected that the movement area will be expanded to include gateways and vehicle docking areas. All types of vehicles (ranging from service vehicles, such as baggage carts and personnel carriers, to all sizes and types of aircraft) are included in the control function. Safe and effective control must be maintained in all types of weather and visibility conditions and with increased traffic projections. The airport surface traffic increases as a function of air traffic operations; more air traffic operations means much more airport surface traffic.

The FAA has an ongoing effort to investigate ways of providing enhanced services which aid air traffic control (ATC) personnel and aircraft crews in performing their assigned tasks. This report presents the results of an industrial survey conducted to determine the status of available components, systems, and technologies which can be applied to airport surface control. Included in the survey were features which provided vehicle/object detection, location, and identification as well as features which conveyed information to vehicle operators such as signs and lights. The survey also addressed features available for improving the control elements on the airport surface and the compatibility with other airport surface control programs.

1. INTRODUCTION.

1.1 PURPOSE.

The purpose of this report is to present an assessment of currently available components, systems, or technologies which can be used to improve airport surface control.

1.2 GOALS AND OBJECTIVES.

The primary goal of the Visual Guidance Program is to increase the safety of airport surface movements and to increase the traffic capacity of airports in all visibility conditions. To meet these goals, the following objectives must be achieved, namely:

- Improvement of detection, identification, and location of aircraft, support personnel, and other objects on the airport surface.
- Perfection of visual guidance and signaling aids to provide clear and unambiguous directions to vehicle operators.
- Incremental introduction of automation capability.

1.3 SCOPE.

This report identifies existing components, systems, and new technologies which could be used to achieve an integrated solution to airport surface control. At present, a number of "discrete" technologies in the area of visual aids are used to facilitate airport surface traffic control. However, there seems to be no centralized, integrated approach toward meeting goals and objectives.

The primary elements of airport surface guidance systems examined in this report are:

- Object detection, location, and identification.
- Visual aids, illumination, signs and markings.
- Power distribution, control, and alternate power sources.
- Control and sensor signal communications.
- Voice and data communication to aircraft operators and other personnel.
- Automated or robotics vehicle control.
- Human factors.

The primary focus is on the airport surface movement area, which refers to runways, taxiways, and other areas used for taxiing, takeoff, and landing. Specific approval from air traffic control (ATC) is required for entry into the surface movement area. Traffic in "non-movement areas", which refers to those not under the control of ATC, is generally slow moving and is primarily controlled by the air carriers or airport operators.

1.4 BACKGROUND.

The safe and effective control of vehicles on the airport surface is a major element of the FAA mission. Close encounters of vehicles with each other or with fixed objects on the airport surface have potentially the same devastating consequence as midair encounters. Control of vehicles on the airport surface is further complicated by the extremely high concentration of vehicles/objects and the variety of vehicle sizes, types, and functional purpose. Safe and effective movement on the airport surface requires all the same functions of the airborne traffic control system as well as additional features. Guidance information is disseminated to vehicle operators by radio as well as visual signs, lights, and markings. Visual guidance aids are an important part of airport surface control. They are the primary aids used by vehicle operators to orient themselves on the airport surface and to navigate to their assigned area.

To accommodate airport surface movement and control under reduced visibility conditions, the FAA has issued Advisory Circular (AC) 120-57, Surface Movement Guidance and Control System (SMGCS). SMGCS defines the standards for airport surface control systems and the authorization of aircraft, vehicle, and personnel presence and movement under reduced visibility conditions.

SMGCS only partially defines the means of determining the separation of ground objects and its influence extends only to reduced visibility conditions. Current operational procedure is to reduce the number of authorized objects on the movement area in reduced visibility conditions.

The objective of this study and other companion FAA projects is to explore the use of components, systems, or technologies for increasing the effectiveness of surface control in all visibility conditions while reducing the possibility of incidents.

2. TECHNOLOGY ASSESSMENT METHODOLOGY.

The emerging technologies for visual guidance are assessed in terms of maturity, applicability, compatibility, and risk. Each element examined was assigned a rating of high, medium, or low. Maturity reflects the completeness of the design, the thoroughness of testing, and the stability of specifications. Applicability reflects the original intended use of the element. For example, an item such as video motion detector technology is very mature in the security industry, but has not yet been applied to airport traffic control. Compatibility refers to the assessment of the technology within the framework of the FAA mission and the NAS elements. Risk is an assessment of the potential risk associated with system deployment. Factors contributing to the determination of risk include failure rate, false alarm rate, and human factors.

Although cost is an important consideration, it could not be used as a ranking criterion for this study. The application of the devices, systems, and technologies considered in this study require much more system definition before credible cost projections could be determined. Items such as the number of sensors required to determine velocity, size of an aircraft on the surface, or the resolution of a ground navigation system have not been determined.

The following sources of information were considered for the development of this report:

- a. Meetings and discussions with FAA and airport personnel.
- b. Technical journals and reports.
- c. Documents supplied by vendors and consultants.
- d. Telephone interviews with vendors and consultants.
- e. Telephone interviews with systems/technology developers.

The data gathered from the various sources were reviewed to identify key existing and emerging technologies in the area of visual guidance.

3. VISUAL GUIDANCE SYSTEMS.

Some forms of visual guidance, such as surface markings, are completely passive and static, while others are capable of automatic control and activation by either ATC personnel or aircraft pilots. In low visibility conditions, detection and location aids are needed to assist ATC personnel and aircraft crews in the safe and effective control and navigation of airport movement areas. The level of control that can be applied to ground traffic is dependent on the ability to positively locate, identify, and communicate with all aircraft and ground vehicles.

Sensors (individually or combined) can greatly assist in the detection and location process at an acceptable cost. At this time, however, they are limited in the ability to adequately provide identification without a high level of sophistication or expense. Additionally, when connected to a control device, such as position identification and direction signs, sensors can assist in communicating control procedures.

The following sections outline the key technologies of different sensor types.

3.1 OBJECT SENSING SYSTEMS.

Object sensing systems perform the basic function of detecting that an object is on the airport surface area. It is possible by using an array of sensors to augment the basic detection feature to provide a velocity of an object and an estimate of its size. Some of the sensors are capable of providing a characteristic signal which can be matched with stored signal characteristics to discriminate between various types of vehicles.

The current sensor technology reviewed in this report is classified into three major types: coupled sensors, transmit/receive sensors, and cooperative active signal sensors. Figure 3.1 shows the further breakdown of these classifications to the specific implementation technology.

Table 3.1 follows this section as a summarized object sensing technology assessment. The various classes of sensors are rated on a scale of high, medium, or low for maturity, applicability, compatibility, and risk as these criteria relate to an airport installation.

3.1.1 Coupled Sensors.

Coupled sensors are those which require the detected objects to impart some characteristic to the sensors domain. For the inductive loops and cable pairs, this is the ferromagnetic or conductive characteristic of the object. For the fiber optic or piezo sensors, this is the force (weight) which the object transfers to the sensor.

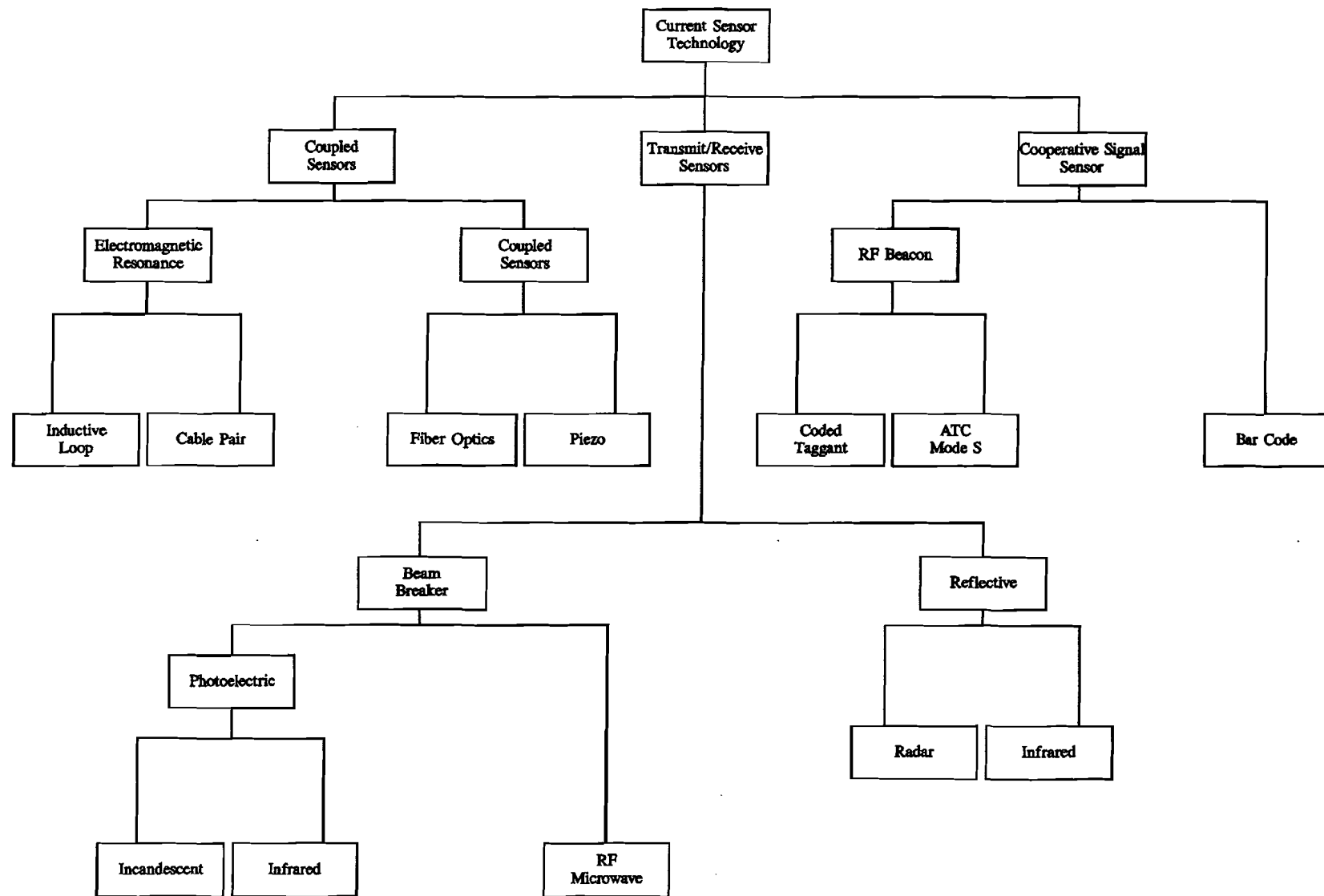


FIGURE 3.1. CURRENT SENSOR DETECTION TECHNOLOGY

3.1.1.1 Electromagnetic Field Sensors.

These devices detect the presence of an object which changes the characteristics of either an inductive loop or a closely coupled cable pair.

Inductive loops are loops of wire embedded in surfaces of taxiways and runways. In combination with appropriate electronics, they create a well-defined electromagnetic field. When activated these loops have electrical characteristics which are affected by the proximity of nearby objects. The inductance of the loops will be increased by ferromagnetic objects or decreased by conductive objects which interact with the electromagnetic field. This change in electrical characteristics will cause a detectable change in an electrical circuit whose resonant frequency is determined by the loop inductance. The most common use of the loops is in roadway traffic light control and controlled access to highways.

In addition to detecting an object, more elaborate inductance loop arrays have been used to provide a characteristic profile signal. This application is most often used to detect the presence of a specific known object in a multi-object environment. The ability to distinguish between ferromagnetic objects like automobiles, trucks, and baggage carts and purely conductive objects, such as aluminum aircraft, may be of use for airport surface control. This theoretical characteristic needs verification.

Inductive loops and cable pairs can also be used in a shared manner as an interrogation antenna for low radio frequency identification tag or transponder systems. A coded signal from the loop system interrogates a "taggant" on the vehicle, which in turn transmits an identification code.

Coupled cable pairs operate on a similar principal. An electromagnetic field is established between a transmit and receive cable pair and the characteristics of the field are changed by an interfering object. A main difference between loops and cable pair is the geometric configuration. Loops are localized to detect objects within the loop area; whereas cable pairs have been used to monitor linear perimeters of 30 kilometers in length.

The main advantages of coupled sensors are the high stability and low maintenance of the devices once properly installed. They also have relatively low component cost. The literature claims reliable performance in rain and snow but no performance figures are provided.

There are some characteristics of coupled devices which cause concern as to their application to airport surface control. One concern is the detection coupling range of approximately three feet above the surface. This is suitable for automobiles and trucks but may not be suitable for large aircraft whose main conductive surface can be five to seven feet above the tarmac. Another concern may be the size of the loops. Most of the loops have been designed based on highway lane widths and automobile length. Using inductive loops for airport surface control may require a redesign of the loops and associated electronics.

3.1.1.2 Force Coupling Sensors.

These devices operate on the principal that a mechanical force applied to the sensor will change the electrical characteristics of the sensor and produce a useable signal. The two technologies reviewed were piezo electric and fiber-optic sensors. For application to airport surface control, both of these sensors require that a vehicle's weight couple a force to a sensor embedded in the taxiway/runway surface. The force coupling mechanism determines to a large extent the operating characteristic of these sensors.

Force coupling systems have experienced installation problems on airport surfaces. A system using piezo coaxial cables was deployed in the taxiways at Baltimore-Washington International (BWI) airport. This system was part of an airport security techniques evaluation program. At BWI an array of sensors was embedded in the taxiway surface using saw cuts to produce 1- by 1-inch channels into which the cable was placed. A protective coating of a silicone polymer and epoxy resin was applied as the force coupling material. The objective of the piezo array was to detect aircraft presence, determine direction and velocity, and to generate a class configuration signal. The class configuration signal was used to correlate with prerecorded aircraft class signatures. Initially, the BWI system performed as expected but the system performance deteriorated with wear. The transfer of the force from the surface to the embedded cable became erratic and unreliable. Apparently the channel sealant could not withstand the mechanical action of repeated taxiway movement and maintenance.

Discussion with the technical director at AMP, Inc. who supplied the BWI Sensors, revealed that they know about the installation problem and that they now know how to provide a stable installation.

3.1.1.3 Piezo Sensors.

Piezoelectric (piezo) sensors come in a variety of configurations from paper thin strips to fabricated coaxial cables. Piezo coaxial cables use piezo material as the dielectric between the center conductor and the outer shield. Mechanical stress changes in these materials caused by pressure from vehicles generate signals which can be detected and used to activate a control function. Industrial research activities are in process to investigate the signature characteristics of these devices.

Piezo detection devices have been used as part of the Allied Signal Stop Bar intersection control system. These systems are currently in evaluation but no data are available.

Concerns were expressed about the performance of piezo sensors at cold ambient temperatures. The technical director at AMP Inc., a major supplier of piezo sensors, is not aware of any cold temperature performance problems. AMP sensors have operated at temperatures of -20°F and laboratory tests have been conducted at -40°F.

3.1.1.4 Fiber-Optic Sensors.

Fiber optics play a dual role in the realm of sensors. They can serve as a communications medium for sensor data or as sensors themselves.

Fiber-optic cables embedded in airport surfaces are subjected to stress when vehicles pass over them and the surface distorts. The resulting strain causes a change in the fiber's light transmission characteristics. This change is detected by a light emitter and detector and associated electronics. These fiber-optic sensors can therefore be used in a manner similar to piezoelectric sensors and can develop signals characteristic of the passing vehicle. This ability renders them as a possible identification classification and verification tool.

Systems based on this premise are currently used as perimeter intrusion detection systems. Depending on the installation, the system is capable of detecting and distinguishing between animals, humans, and vehicles.

A system proposed by one vendor is currently being evaluated by the Huntsville, Alabama, municipal airport. This system will use an array of embedded fiber optic pressure sensors to detect, monitor, and classify (large, medium, and small) aircraft and other vehicles on the airport surface. The objective of this system is to monitor surface traffic for revenue purposes, not for surface traffic control. The full extent of the Huntsville system is not known. It is conceivable that it could be applicable to airport surface control. Some effort to coordinate with the Huntsville Airport Manager should be considered as a follow-up action.

The application of fiber optics for sensor signals solves several problems encountered on airfields. The fibers are resistant to the corrosive effects of contaminated water which may leak into their jackets and which may also short circuit metallic conductors. Since the fibers are not electrically conductive, they are also immune to electromagnetic interference such as lightning strikes.

Another application of fiber optics is in their use as light pipes to conduct light from remotely located sources. This use is especially suited for visual devices installed in hard-to-reach locations, such as obstruction lights on tall towers.

The main concern of all of these embedded techniques is the ability to withstand the traffic and maintenance environment of an airport surface. Experience by the FAA at Baltimore-Washington International (BWI) airport showed significant deterioration in detection performance due to mechanical installation problems.

3.1.2 Transmit/Receive Sensors.

Transmit/receive sensors require a transmitter which generates a signal with known characteristics and a receiver which recognizes that signal or changes in its characteristics. These types of sensors can be further classified as reflective types which rely on the backscatter reflection characteristics of an object or as "Beam Breakers" which rely on an object interrupting the transmission path to the receiver.

3.1.2.1 Beam Breakers.

Beam breaker sensors, as the name implies, rely on the total or partial interruption of a beam between a transmitter and receiver. The technology used to form the transmitted beam, to a large extent, determines the effectiveness of the sensor in any given application. Many of these devices were designed for the process control industry with very high resolution (millimeter), short range (less than one meter), and were not considered applicable for airport surface control. Only those devices used for vehicular detection with a range of 200 ft. or more were considered in this survey.

Photoelectric sensors have a long history in beam breaker object detection. The early technology relied on low-cost incandescent light sources for the transmitted beam. A 300-watt lamp will provide a detection range of 450 ft. with an expected lamp life of 2000 hours. One feature of incandescent beams is they are highly visible by humans without auxiliary equipment, whether this is a benefit depends on the maintenance philosophy used.

Most developers of photoelectric sensors have designed products to use an infrared light source for the transmitted beam. Infrared transmission provides better resolution, improved directivity, less power consumption, and longer source life for a given set of detection criteria. The performance data supplied indicates reliable detection in heavy fog conditions (San Francisco Bay Bridge) at a 200-ft. range for an 800-nanometer IR source. Another manufacture has a dual IR system with a 500-ft. range which operates in all outdoor climatic conditions.

Of all the sensors reviewed in this survey the 800-nanometer infrared sensors have the most direct applicability to airport surface control without any product design modification or obvious installation procedure development.

RF microwave sensors can also operate on the beam interruption basis. These sensors operate in either the X-band or K-band frequency range. Units are available with detection ranges of 350 ft. The literature claims better performance in heavy rain, snow, or dust than infrared sensors. The main concern with RF sensors is the potential susceptibility to other X-band or K-band radiation in or about the airport environment. RF beam breaker sensors have been used in conjunction with the ADB Siemens stop bar runway/taxiway intersection control system. No data are available at this time.

Correlation with the FAA spectrum management division and with the Electromagnetic Compatibility Analysis Center (ECAC) spectrum model for airports is recommended as a first step before considering any RF system in the airport environments.

3.1.2.2 Reflective Sensors.

Reflective type sensors are well characterized by surveillance radar such as ASDE-3 and video cameras. Radars are self contained in that they provide their own signal source whereas video cameras rely on ambient light or object self-radiation (IR) for illumination. Basic radar needs

significant signal processing and system augmentation to provide additional information such as object motion and identification.

The FAA has a well developed program for airport surface detection equipment (ASDE) and is now in the process of developing/deploying the ASDE-3 radar system. The FAA has decided that the ASDE-3 radar will be deployed only at key critical sites; it is not being designed as a general airport surface control system. ASDE technology in combination with other ATC functional equipment, such as MODE-S, are prime items in the FAA's Airport Surface Traffic Automation (ASTA) and Airport Movement Area Safety System (AMASS) systems. This report does not cover these programs.

There is a family of IR detectors which rely on a reflected energy. These sensors were not actively considered in this survey because their detection performance with highly reflective objects (like aircraft) is not very good.

Video cameras operating in either the visible light spectrum or the infrared spectrum have one major drawback, they require a human operator to monitor and perform the detection and identification patterns.

3.1.2.3 Acoustic Sensor.

Ultrasonic acoustic sensors are currently being used to detect objects in monitored areas and then perform an action such as opening a door or sounding an alarm. These type of systems use active sound transmitters and a receiver in either a beam breaker or backscatter arrangement. Sonic sensor performance has been acceptable in selected environments with known noise characteristics. Performance in airport surface environments has not been investigated. Another limiting factor is the range over which reliable detection can be achieved. Current usage is less than forty feet. The literature did not reveal any active effort in applying this technology to the airport surface control environment. The potential use of acoustic sensors in an airport movement area will require both technical studies of the airport acoustic environment and considerable application engineering.

3.1.3 Cooperative Signal Sensors.

This classification includes all sensors which require placing a cooperative device on all vehicles which have access to the airport surface movement area, such as aircraft and support vehicles. RF beacons and optical sensors are the subclassification included in this section.

3.1.3.1 RF Beacons.

RF beacons such as the Air Traffic Control Radar Beacon System (ATCRBS) and MODE-S are used extensively in modern air traffic control systems. Both of these systems rely on electronic transponders on board the aircraft. The aircraft transponder responds to a ground based interrogation with specific information in a coded transmission. ATCRBS uses the 3A and 3C modes to obtain aircraft identity and barometric altimeter readings. Mode-S uses the same

technique as ATCRBS but has a more extensive request/reply message capability. Current FAA/ATC operational procedures require that these beacon transponders be turned off on the airport surface to reduce the RF noise and code garble potential caused by many aircraft in close proximity. Studies are underway to investigate a very low power interrogation/reply system which would not cause interference with normal ATC use of ATCRBS or MODE-S transponders. This information is provided for completeness of the study; no assessment has been made on the use of these systems for airport surface control.

3.1.3.2 Bar Code Systems.

Bar code systems can perform the basic function of object detection and the added feature of identification. This popular technology has found application in all types of environment including monitoring high-speed railroad traffic. The bar code system requires placing a bar coded emblem on the vehicle in a position which can be viewed by a bar code scanner. The assumed reluctance to placing a large visible bar code emblem on an aircraft and the limited maximum detection range of seven feet may significantly restrict the application of the bar code system for airport surface control.

3.2 OBJECT LOCATION & IDENTIFICATION SYSTEMS.

Object location systems add the function of determining where detected objects are on the airport surface. Identification can be very specific as to who the object is, such as AA Flight 123 or just a large object. Location and identification are the beginnings of the navigation and control functions.

3.2.1 Global Positioning System (GPS).

GPS is a position and navigation system which uses signals from a constellation of satellites to determine a GPS user's position in three-dimensional space. An earth referenced receiver uses the precise time and position information from at least four satellites in view to determine the receiver's position. GPS is a system developed by the Department of Defense (DoD) and the position accuracy for civilian use can be restricted by DoD to ± 100 meters. The 100-meter horizontal accuracy is sufficient for non-precision approaches and landings.

Experiments are currently underway by the FAA to investigate means of improving the basic GPS service for use at category I airports. It is possible to improve the position determination accuracy of basic GPS by providing a correction signal as determined by a fixed, known ground reference station. At the ground reference station a GPS receiver correlates the estimated position with the precisely known position and develops a correction signal for each satellite in view. A correction signal is broadcast to all GPS receivers in the coverage area via a datalink such as a geostationary telecommunications satellite. All GPS user receivers can use these corrections to improve the position determination estimate. Current experiments at the FAA Technical Center have demonstrated reliable position determination using differential GPS (DGPS) to a horizontal accuracy of less than ± 20 meters. This position estimate is sufficient for Category I approach and landing.

TABLE 3.1. OBJECT SENSING TECHNOLOGY ASSESSMENT

CLASSIFICATION	ITEM	MATURITY	APPLICABILITY	COMPATIBILITY	RISK
Electromagnetic Field	Inductive Loop (1)	High	Med	Med	Low
	Cable Pair (1)	High	Med	Med	Med
Force Coupled	Fiber Optic (2)	Med	Med	Low	High
	Piezo (2)	Med	Med	Low	High
Beam Breaker	Incandescent Photoelectric (3)	High	High	High	Low
	Infrared Photoelectric	High	High	High	Low
	RF Microwave	Med	Med	Med	Med
Reflective	Radar (ASDE-3)	High	High	High	Low
	Video Cameras Detectors (Infrared)	High	Med	Low	Med
RF Beacon	Coded Taggant (4)	Low	Low	Low	High
Acoustic	Acoustic	Low	Low	Low	High
	Bar Code	High	Low	Low	High

NOTES:

1. Based on High Cost of Retrofit
2. Based on BWI Experience
3. Incandescent Technology Has Been Overtaken
4. Popular New Technology - Used For Airport Landside Vehicle Identification

Other techniques have been used by topology surveyors to achieve GPS position accuracies of 2.5 centimeters. This is achieved by using a technique known as Carrier Phase Detection. This accuracy is not achieved in real time, but is the result of significant post processing of the signals to determine and correct the error sources. A technique known as Kinematic Carrier Phase Detection is currently being investigated by the navigation community. Theoretical studies indicate that accuracies of 10-15 centimeters can be achieved in real time (6 seconds or less).

The feasibility of using some enhanced form of GPS for real time surveillance of airport surface traffic is being conducted by Aeronautical Radio Inc. (ARINC) at the Chicago O'Hare International Airport. No published data was available at the time of this study.

Another use of GPS for surface control was demonstrated by the FAA at the Manchester, New Hampshire Municipal Airport. This system correlated the aircraft's ground position as determined by GPS with a precise topological map of the airport, including runway, taxiways, and obstructions. This information was presented to the pilot as a navigational aid. The application of this type of system to airport surface control would require significant augmentation of airport mapping and communication services between ATC and vehicles. Another fact to consider for this system is that the GPS position estimates were done before the DoD invoked the 100-meter accuracy restriction.

The GPS system has the potential to improve airport surface control and navigation. Specifically how GPS can be used and what accuracies are required for airport surface control have not been determined as yet.

3.2.2 Mode S Datalink.

Mode S Datalink uses a ground-based radar to communicate with the aircraft for various flight-related information such as updating flight plans, obtaining clearances, etc. It provides the data exchange medium between TCAS equipped aircraft. It also communicates with ground based Mode S sensors which set TCAS sensitivity levels based on traffic density.

The use of Mode S datalink for surface traffic control is being investigated in the ASTA project. The present system would have to be adapted to an airport traffic environment. Also, techniques would have to be developed to correlate object location data with flight plan information.

3.2.3 Traffic Alert and Collision Avoidance System (TCAS).

The Traffic Alert and Collision Avoidance System (TCAS II) is a radar-based beacon system which interrogates transponders on aircraft to measure bearing, distance and altitude separation, and closing rates in three axes. TCAS provides warning information and commands to the crew when the protected volume of airspace around the aircraft is being violated. The TCAS antenna generates a narrow beam to restrict the number of aircraft replies in an interrogation. At present, TCAS is used only when the aircraft are in flight.

An effort was undertaken to upgrade the existing system to TCAS III by using a more complex antenna that could precisely measure the bearing angle to other aircraft as well as the rate of change in bearing. But tests have demonstrated that such an update is not technically feasible; therefore, the effort was abandoned.

TCAS is included in this report as a technology which can be used for intrusion detection and not as an implementable system.

3.2.4 Automatic Dependent Surveillance (ADS).

The Automatic Dependent Surveillance (ADS) system is being implemented to increase air traffic capacity and improve safety margins in oceanic airspace. Radar surveillance is not feasible in oceanic airspace. ADS uses a satellite datalink to provide the aircraft's position as determined by the on-board navigation system when interrogated via geostationary communication satellites. ADS also provides an interactive datalink via satellite. The ADS system is being tested in both the Pacific and Atlantic Ocean environments. The concept of obtaining position information from the aircraft in real time has been demonstrated by ADS. This technique may have an application in airport surface control.

3.2.5 Cockpit Displays.

Multi-function cockpit displays (MFD) have been in wide use in aircraft to display the aircraft status. Many limited function instruments such as altimeters and attitude indicators, which are precision mechanical instruments, are being replaced by general purpose displays coupled to electronic control boxes which generate the display image. One or more of these displays, whose functions are not in use during ground movement, can be shared by ground navigation functions.

Head up displays (HUD), widely used in military aircraft, can be particularly useful in presenting a navigational pattern superimposed on the actual ground scene. These displays project a virtual image superimposed on the actual scenery. A HUD is implemented either in a crewman's helmet with eye projectors or as a control panel projector whose image is superimposed on the outside scene by means of a partially reflecting mirror. Helmet projectors would be impractical in commercial or private aircraft. Some airlines have already incorporated HUD and the reaction from the pilots has been very favorable. While this could easily be designed into a new aircraft, it may be difficult to retrofit into an existing aircraft or general aviation aircraft. HUD is an output device for the pilot. The method of correlation with ATC data sources has not been developed.

The FAA has incorporated HUD in the High Performance Research Vehicle (HPRV) at the FAA Technical Center as part of the Driver's Enhanced Vision System. HPRV is a prototype of an advanced crash-fire assistance vehicle which significantly improves response time to emergency situations, much of which is attributed to the information provided on the HUD.

3.2.6 Video Image Analysis.

Video imaging, by the use of video cameras followed by image analysis, can provide both location and identification data. Current television camera resolution, while adequate for object detection, is marginal for resolving identification labels on aircraft. High Definition (HDTV) television cameras may have the necessary resolution. Charge Coupled Device (CCD) arrays with ten times the resolution of present cameras, i.e., 5000 linear pixels, are available.

In one form of analysis, video motion detectors store some characteristics of earlier frames of a video signal and compare them with the characteristics of later frames. If a significant change is found then an alert signal is emitted. These units have been deployed in security installations and present units have relatively low resolution. They are dependent on video cameras to gather the signals for them. This alert can then trigger analysis for location and identification.

The suitability of standard camera resolution (300 - 400 linear pixels) is dependent on the desired discrimination. Significant changes in the image, such as those due to the passage of a vehicle through the path, should trigger the detector. The system should be able to discriminate significant events from non-significant events, such as the passage of a cloud. Video motion detectors using Far Infrared sensors may be especially suitable to poor visibility conditions such as fog.

3.2.7 ASDE-3.

The FAA has instituted the Airport Surface Traffic Automation (ASTA) systems programs to improve ground safety and increase throughput. The core of these systems is the ASDE-3 (Airport Surface Detection Equipment) radar set. It is a ground based radar system monitoring surface traffic. When more than one radar is required to obtain complete coverage of the maneuvering areas, the multiple radar reports are combined into a comprehensive mosaic and the output is transmitted to the tower for processing and presentation on one or more displays.

Concerns have been expressed about ASDE in terms of its accuracy and high cost. Accuracy issues stem from the fact that the image of an object does not seem to keep pace with the object's movement because of data processing deficiencies. Faster data polling and processing techniques could alleviate these problems. The unique topology of each airport and the location of ASDE equipment presents the possibility of blind spots and signal interference caused by building obstructions.

ASDE-3 radars are presently being installed at selected airports under an FAA contract. They are designed to help ground control provide safe taxiing guidance to aircraft in poor-visibility conditions. The FAA is sponsoring an effort which uses ASDE-3 in an automatic incursion-alert system, called Airport Movement Area Safety System (AMASS), which can be used to warn controllers of unauthorized movements and possible runway incursions.

3.2.8 Radio Frequency Identification.

Radio frequency (RF) identification system consists of tags, antennas, RF modules, signal interpreters (readers), and a system processor. Coded taggants are devices like ATC beacons which respond to an interrogation signal with a coded reply. Depending on the method of interrogation, these systems can be used for detection as well as identification. The current use of RF taggants is for vehicles which are constrained to predictable paths such as highway lanes, railroad tracks, or entrance portals. The maximum range of sixty feet does not make these devices an attractive alternative for airport surface control even if the problem of mounting another RF emitter on the aircraft could be overcome. It may be possible to use RF taggants with the interrogator embedded in the runway/taxiway surface. This would overcome the limited range, but would then be constrained by the potential problems experienced by all types of embedded sensor installations. Tags are small electronic devices attached to the vehicles and encoded with their identification information. As the tagged object approaches an antenna station, a periodic interrogation signal is broadcast. Upon reception at the taggant the signal is modified and reflected back to the antenna. This reflected signal carries the identification code for that object. The reader interprets the ID code from the signal and validates it based on system adaptation defined criteria. It can also append other information such as time and date of object detection. The reader transmits the ID codes to a host computer and/or data logging system.

3.2.9 Near Infrared Video Cameras.

The charge coupled device (CCD) image scanners used in current video cameras have a silicon photo sensitive surface. These silicon surfaces are sensitive from the ultraviolet to the near infrared region. The ultraviolet sensitivity can be limited by the absorption and reflective characteristic of the glass in the cameras lenses. Infrared sensitivity is a limit of the silicon itself. These cameras can detect radiation in the near infrared spectral range of 0.75 to 1.0 micron. If the camera is equipped with a filter which excludes visible and ultraviolet light, it can operate in the near infrared spectrum. This mode of operation is useful in security situations for surveying darkened areas illuminated by infrared sources. Such cameras are supplied by a variety of vendors.

In the presence of material suspended in air, such as fog or snow which results in reduced visibility conditions, light is scattered more effectively when its wavelength is commensurate or shorter than the dimensions of the particles. Infrared cameras would be more effective in penetrating fog. Near IR cameras may give a twenty to forty percent increase in penetrating power over visible-light cameras.

3.2.10 Far Infrared Video Cameras/Thermal Imagers.

These cameras have been used for non-time critical purposes, such as engineering studies or environmental surveys. Recently Texas Instruments released a lower cost camera operating in real time for security and law enforcement purposes. Grumman is also developing such cameras. Cameras operating in the 10-micron region would have ten to twenty times the penetrating power that is available with a visible camera and would detect an object's self-emission.

The FAA is now evaluating a Forward Looking Infrared (FLIR) camera produced by Westinghouse, in combination with a HUD to enhance the response of a rescue vehicle under reduced visibility conditions.

Table 3.2 provides a high, medium or low rating to each of the technology areas in terms of maturity, applicability, compatibility, and risk.

TABLE 3.2. OBJECT LOCATION AND IDENTIFICATION SYSTEM ASSESSMENT

ITEM	MATURITY	APPLICABILITY	COMPATIBILITY	RISK
GPS	High	Med	High	Low
Mode S	High	Med	Med	Low
TCAS	Med	Med (1)	Med (1)	Med
ADS	Med	Med	Med	Med
HUD	High	Med (2)	Med (2)	Med
Video Image Analysis	Med	Med	Med	Med
ASDE-3	Med	High	High	High
RF Identification	Med	Low	Low	Med
Near Infrared Video	High	Low	Low	Low
Far Infrared Video	Low	High	Med	Med

Note: 1. The use of ATC beacons on the airport surface needs to be considered.
 2. HUD needs correlation with ATC data bases - this has not been considered as yet.

3.3 VISUAL AIDS.

Visual aids serve the function of defining the different areas of the airport surface; they are also a principal means of conveying this information to the aircraft pilot. The addition of a control feature makes visual guidance an effective navigation system for airport surfaces. Signs and markings represent the most basic form of a visual guidance system. To date, they provide location and guidance assistance to support control instructions issued by air traffic controllers. To this extent, the control potential of visual aids can be improved by further defining specific locations on the movement areas and by adding the capability to alter their presentation, i.e.,

color or signal (flashing, steady, etc.). Several categories of signs and markings are described in the FAA Advisory Circulars, Standards for Airport Sign Systems (150/5340-18) and Marking of Paved Areas on Airports (150/5340-1) which are used to define the meaning of both color and signal. All system enhancements must be consistent with accepted standards.

The use of addressable signs on airports has, to date, been limited to landside application and to certain apron applications, such as docking guidance systems. The use of addressable signs on the airfield, particularly at complex taxiway intersections, offers the potential for significant benefits. Arrays of lighted visual aids outline the runway and taxiway edges to identify the airport uniquely from the air and to facilitate ground movement. These systems are described in FAA Advisory Circular, Runway and Taxiway Edge Lighting Systems (150/5340-24).

3.3.1 Stop Bars.

Stop bar systems were developed in an effort to eliminate runway incursions, especially in limited visibility conditions. Stop bar systems provide the tower ground control with the ability to control a set of high-visibility lights embedded across the taxiway surface at taxiway/runway intersection points. These systems require a controllable set of lights, a remote light control system, aircraft detection sensors, a data acquisition and distribution system, and a tower display and control system.

Earlier systems used radio remote control as on-off control for the light source. Timers were used to reinitialize the enter/don't enter conditions after an aircraft was permitted to access the intersection. Newer systems use power line control signal technology and aircraft presence sensors (see section 3.1) in place of timers. These enhancements offer selective control and monitoring of individual light assemblies and light intensity.

3.3.2 "Wig-Wag" Lights.

The L-804 "Wig-Wag" light system was developed to enhance identification of entrances to active runways at intersections with traffic conflict problems. They function similar to a railroad crossing signal, with alternate flashing of two yellow lamps sited adjacent to the holding position. Lack of effectiveness in the higher visibility conditions and the adequacy of the flash rate has prompted the FAA to evaluate and revise the existing L-804 specifications.

3.3.3 Lasers.

Laser technology has great potential to improve visual landing and ground guidance aids. Laser light sources have two advantages over other light sources: (1) they are spatially coherent, which facilitates controlling the distribution of their light; and (2) they are monochromatic at their operational wavelengths, which allows close control of their color characteristics. The monochromatic feature permits higher luminous efficacy compared to filtered incandescent lamps, even when the energy conversion efficiency of the laser is low, since power from unwanted wavelengths is not discarded by absorption in the filter.

Lasers have some disadvantages compared with conventional light sources. They are usually more complex, with an associated decrease of reliability. Gas and chromatic dye lasers, which are most suitable for purpose of illumination, contain components which are extremely sensitive to aging and thus shorter lives can be expected for laser illuminators. Because of their complexity and the need to control tight mechanical tolerances, lasers tend to be much more expensive than the lamps they might replace. The tight mechanical tolerances also lead to reduced ruggedness. Since the lasers may need an associated mechanical scanning system to support image formation, further unreliability may be encountered.

In spite of these deficiencies, lasers may offer advantages absent in other visual aid illuminators. Lasers have high intrinsic brightness making them extremely visible. Because of spatial coherence, laser light can be projected in very narrow beams. The penetration of obscuring atmosphere is enhanced by the coherence. Some lasers, such as argon ion lasers and chromatic dye lasers, can emit at several wavelengths yielding different primary colors. These can be combined to give the visual effect of a full spectrum of colors; however, the exact color sensed may depend on the observer. The light from lasers can be coupled to an optical fiber distribution network with less loss than that from incandescent lamps, including tungsten halogen lamps. This light can also be distributed by means of scanning mirrors to a fiber array. Some lasers can be electrically modulated and can become the basis for reconfigurable signs. GTE Laboratories demonstrated a projection television using this technology in the early 1970's. At present this technology is used mainly in entertainment displays, e.g., disco light shows.

Coupled to a fiber-optic light pipe bundle, laser light from a single source can be distributed to a number of fixtures, such as runway/taxiway edge markers or stop bar lights.

Laser technology can be the basis for the future development of new features or functions for airport surface control. The state of the art has not been applied to airport visual landing and guidance control.

3.3.4 Fiber Optics.

Fiber-optic technology offers significant enhancements to airport lighting technology. It is inexpensive to produce, chemically neutral, immune to lightning strikes, easy to maintain, consumes less energy, and has been extensively used in the communications industry. Fiber-optic airport signs have been developed and installed in many locations. They use traditional light sources with message characters illuminated by light delivered through fiber-optic bundles.

An experiment was conducted in 1987 at Edmonton Municipal Airport in Canada whereby the taxiway guidance signs were converted to fiber optics to permit a full-scale operational evaluation. The reaction to the sign illumination was reported to be overwhelmingly positive from all segments of the aviation community in terms of improved readability and visibility, especially in a fast-moving situation and poor visibility conditions. However, the conversion to fiber optics caused the individual characters to be illuminated, not the entire sign face. Rather than presenting white characters on an illuminated red background, this system presented red characters on a non-descriptive background. This is not in accordance with all FAA approved signage standards.

3.3.5 Alternative Lighting.

Electro-luminescent (E/L) panels are composed of very thin sheets of phosphor in an insulating support material. The phosphor is stimulated by an electric field to produce visible light. Advantages of this technology include a lack of heat to dissipate, low energy consumption, no filament to burn out, and ability to be formed into specific shapes. In the past this technology has suffered from relatively low attainable light output and the high cost of constructing E/L panels. In recent years the use of higher excitation voltages and improved phosphors have served to overcome these drawbacks.

Recent news articles reported of a breakthrough where a magnetic coil is used to generate a radio signal which stimulates a plasma, causing the phosphor to glow. Such a technique could lead to a revolutionary light bulb with over 20,000 hours of life and use 75% less electricity than comparable incandescent lamps. An industry working group has recently been formed to develop new standards for this type of lighting technology.

3.3.6 Holographic Signs.

Two- and three-dimensional holograms are created by exposing special holographic film of the subject backlighted by a laser light source. Its color properties are determined by the laser light. The hologram image can then be mounted on a substrate material which can be illuminated by another light source, such as incandescent or neon. The display holograms presently produced are smaller than that required for aviation applications. The cost of a large laser required to produce larger size holograms can be a limiting factor.

Table 3.3 provides a high, medium, or low rating to each of the technology areas in terms of maturity, applicability, compatibility, and risk.

TABLE 3.3. VISUAL AIDS ASSESSMENT

ITEM	MATURITY	APPLICABILITY	COMPATIBILITY	RISK
Stop Bars	High	High	High	Low
“Wig-Wag” Lights	Med	High	Med	Med
Lasers	Med	High	Med	Med
Fiber Optics	High	High	High	Low
Alternative Lighting	Med	Med	Med	Med
Holographic Signs	Low	Note (1)	Note (1)	High

Note: 1. Considerable Human Factors studies need to be done to determine the applicability of holographic signs and compatibility with FAA/NAS environments.

3.4 COMMUNICATION AND CONTROL SYSTEMS.

The effective control of the airport movement area requires a function for collecting system status data and disseminating device control signals. The airport surface is the most enriched radio frequency area in the NAS and probably in all the civilian world. Many systems such as GPS, Mode S, and TCAS depend on radiated signals and their performance may be compromised in the airport environment. The benefit of using non-radiating systems for the data collection and control function are appreciable.

Several visual aid control technologies are available for remote control of high-intensity light and other adaptive visual aids in the airport environments. The high currents and power required for airport visual aids requires a well-engineered integrated system. Many systems use a remote field circuit switch with user-dedicated control line to control blocks of lights. The control system uses constant current regulators to provide a gradual lamp turn-on/turnoff feature which significantly improves lamp life.

Many newer installations are using power line communication devices to remotely control airport visual aids. These systems use the same cable for both power delivery as well as control signal distribution. Each controlled element has a device which extracts the command signal from the power supply lines; no separate control distribution system is required. Another benefit for a power line communication system is increased control capability, since each lamp requires a power delivery cable it is much easier to individually control and monitor each lamp.

By necessity, the airport surface requires buried cables. Potential surface obstructions must be kept to a minimum. Buried cables require costly installation and periodic maintenance. Buried

metallic conductors are subject to corrosive galvanic action and are subject to destructive lightning impulse surges. Fiber-optic cables are chemically inert and are not affected by lightning power surges. This is a significant advantage over conventional remote field circuit switch system. Fiber optics are used extensively in control and communication applications.

Fiber-optic technology is not suited to carry the electrical power required for airport visual aids. It is possible to use fiber optics to transmit large quantities of optical power when used as light pipes. This may be a technique which is applicable to airport surface control.

Table 3.4 provides a high, medium, or low rating to each of the technology areas in terms of maturity, applicability, compatibility and risk.

TABLE 3.4. COMMUNICATION AND CONTROL SYSTEMS ASSESSMENT

ITEM	MATURITY	APPLICABILITY	COMPATIBILITY	RISK
Power Line Carrier Communication	Med	High	Med	Low
Remote Field Circuit Switch	High	High	High	Low
Fiber-Optic Control	High	High	High	Low

3.5 ALTERNATE POWER SOURCES.

The airport surface is large and filled with many permanent surface structures and underground distribution systems. Excavating on the airport to provide electrical power to remotely located systems is both costly and disruptive of service. Alternate power sources may be a way of avoiding this problem for new systems.

The addition of active devices to a system will require analysis of additional power consumption. Today's airport power requirements are already reaching maximum capacity. The addition of sensors, lights, and transmission lines will only exacerbate current conditions.

3.5.1 Solar Power.

Solar arrays are typically made up of a number of photovoltaic cells and coupled to a rechargeable battery. Self-contained solar power supplies reduce the expense of importing power while offering high reliability and environment suitability. Solar power devices are used in remotely located FAA facilities.

3.5.2 Battery Technology.

A survey of vendors indicated there is no up-and-coming technology to replace lead-acid batteries as a storage medium for solar power systems. Table 3.5 provides a high, medium, or low rating to each of the technology areas in terms of maturity, applicability, compatibility, and risk.

TABLE 3.5. POWER SOURCE SYSTEM ASSESSMENT

ITEM	MATURITY	APPLICABIULITY	COMPATIBILITY	RISK
Solar Power	Med	High	High	Low
Lead-acid Batteries	High	High	High	Low

3.6 HUMAN FACTORS.

Infusion of new technology in the area of visual guidance for airport surface traffic control must address the concerns, values, and perceptions of all the system's users. Human-centered system design assumes that automation may be valuable to support humans in meeting safety and efficiency goals. However, automation is not to be used simply because it is technically feasible. Automating every task possible leaves the operator with a set of tasks that may be incompatible with human capabilities, limitations, and preferences. The controller may be left with the task of monitoring the automatic system, a task at which humans are not particularly effective. Also the controller may, at times, need to override the automation in order to perform the task efficiently and correctly.

Human-centered system design begins by explicitly considering the role of the operator. This is in contrast to letting it emerge from the tasks that are not automated in a technology-driven approach. Human factors need to be considered from both the tower controller perspective and the cockpit/pilot perspective.

The two technology areas of human factors which can be applied to airport surface control are the Human Factors Laboratory at the FAA Technical Center and aircraft cockpit simulators developed for pilot training and certification. Preliminary engineering model designs should be incorporated into these facilities to ensure compatibility with the special human factors involved with the airport surface control.

Table 3.6 provides a high, medium, or low rating to each of the technology areas in terms of maturity, applicability, compatibility, and risk.

TABLE 3.6. HUMAN FACTORS ASSESSMENT

ITEM	MATURITY	APPLICABIILITY	COMPATIBILITY	RISK
Human Factors Lab.	Low	High	High	Med
Aircraft Simulators	High	High	Low	Med

4. SYSTEM INTEGRATION.

The various components of a visual guidance system work in synergy to complement one another. The interrelationship of individual components must be considered whenever a change is made to any one of them. An integrated and automated surface movement system could utilize a combination of loop sensors embedded into the pavements combined with automated computer tracking and prioritization algorithms to provide segmented sectional lighting control.

The integration of sensor technology, radar data, and datalink offers the potential for a totally integrated and automated surface movement system. A new approach combining the precision of DGPS and datalink capabilities of the Mode S beacon system is under development. This concept will undergo tests at Boston's Logan International Airport next year. These tests are intended to demonstrate that an aircraft equipped with TCAS and GPS receivers can automatically broadcast its position coordinates. The cost to implement this concept would be modest because the facilities required at each airport would consist principally of modified TCAS II and GPS receivers. Additionally, this system will be integrated with the data obtained from an experimental Airport Surface Detection Equipment (ASDE) radar to monitor surface traffic on movement areas. The objective is to evaluate the use of ASDE radar as the basic surface traffic sensor whose target locations would be correlated with GPS position and vehicle identity information transmitted via Mode S datalink.

An essential feature of automated control is system data acquisition and monitoring. The Operational Maintenance and Monitoring System (OMMS) provides these functions. The role of OMMS in airport surface control is equivalent to that of the Remote Maintenance Monitoring System (RMMS) in the NAS.

A system concept which incorporates these systems is shown in figure 4.1, Concept of an Automated Airport Visual Guidance System.

A time-proven, cost-effective way for achieving system integration is to develop a proof of concept test bed. Assessment of system refinements can be done on individual devices and on subsystem combinations. A test bed also provides a means of evaluating competitive implementations. The test bed can be used to develop NAS interface specifications and operational procedures. An Airport Surface Guidance Control Test Bed is a way of developing a comprehensive system for airport surface control improvements.

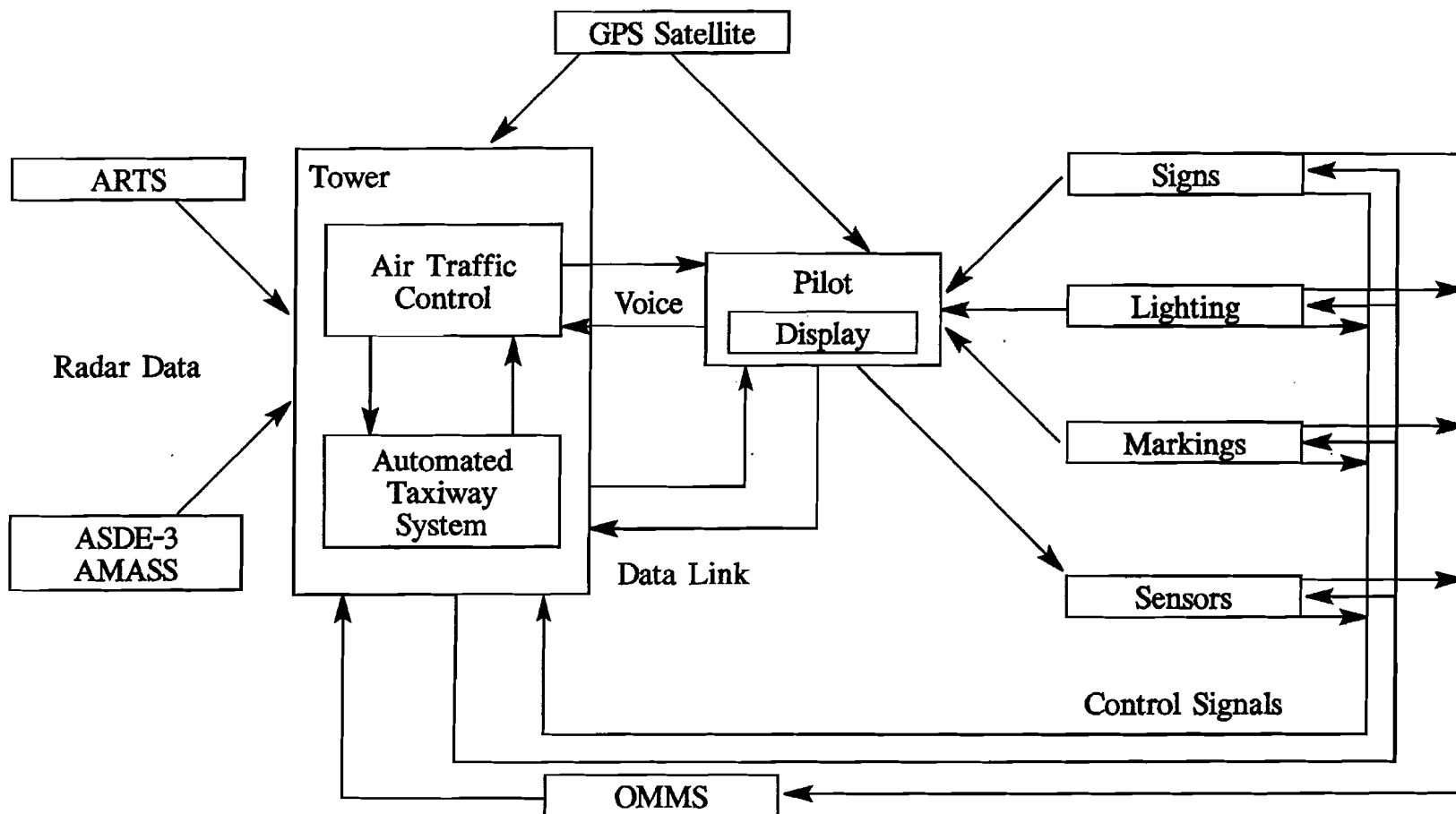


FIGURE 4.1. CONCEPT OF AN AUTOMATED AIRPORT VISUAL GUIDANCE SYSTEM

5. CONCLUSIONS.

The airport surface control problem has the potential of becoming a major concern and of becoming a limiting factor in air travel. The FAA has initiated an ASTA project. ASTA is a comprehensive project based on ASDE-3, Mode S, and other FAA ATC enhancement programs. Much of the new technology suitable for airport surface traffic control will be defined by the ASTA project. ASTA will also define interface standards and protocols which system components must meet.

Although ASTA has great potential, its deployment is in the future and may not be applicable to all airports, especially medium or small airports. There are components, systems, and technologies currently available which can be implemented in the near term. Considerable benefits can be achieved from near term incremental deployments of airport surface control enhancements. The most promising areas for beneficial deployment are improved visual aids, object detection, and identification. Object detection is the most readily achievable goal. Infrared beam breaker devices are available which can provide this feature. Radio frequency beam breakers are also available, but will require an electromagnetic compatibility analysis for each installation. Object identification is a major feature of ASTA, but may be based on radar/beacon technology, such as ASDE and Mode S. The feasibility of using RF beacons on the airport surface has not as yet been proven as a viable alternative. Coded electrical tags placed on vehicles is a possible, interim solution, to object identification. The limited interrogative range can be overcome with better interrogators or by embedding the interrogator in the runway surface.

An important feature of any interim deployment is to ensure interface compatibility with other existing or projected airport control programs.

Some technologies are developing so rapidly that while one can see the utility of such a technology, one cannot easily foresee the availability of products or the standards they can meet.

This report identifies various technologies that can be applied to enhance airport surface traffic control and overall safety. A fully automated and integrated visual guidance system would incorporate the following features:

- A systems engineering approach to visual guidance
- Incorporates new remote sensing and control techniques
- Provides ATC with runway incursion information
- Provides control of the automated lighting and guidance system
- Integrates a datalink between the air traffic control tower and aircraft for transmission of taxiway guidance information

- Provides the pilot with a cockpit display of
 1. computer generated runway/taxiway map;
 2. location of pilot's aircraft; and
 3. location of other aircraft and ground support vehicles in the vicinity.
- Upgrades taxiway procedures/protocols to complement the automated system.

The systems/technologies included in this report have been regrouped in the following tables according to their overall rating in terms of low, medium, and high risk.

TABLE 5.1. SYSTEMS/TECHNOLOGIES WITH LOW RISK

ITEM	FUNCTION	COMMENTS
Inductive Loops	Detection	High Retrofit Cost
Microwave Sensors	Detection	Compatibility with Spectrum Management
Photoelectric Sensors Incandescent & Infrared	Detection	Readily Applicable to Mission
GPS	Location	Needs a Datalink
Mode S	Identification	Needs a Location Adjunct
Near Infrared Video	Detection/Location	Practicality is Unknown
Stop Bars	Visual Aids	Evaluation in Process
Alt. Marking Material	Visual Aids	High Potential, Ingestion
Fiber Optics	Adaptive Visual Aid	Used as Light Pipes and Communications, Not as Sensors
Power Carrier Comm.	Remote Control	Evaluation in Process
Solar Power	Remote Control	Ready Now
ASDE 3 Radar	Detection	ASTA/AMASS

TABLE 5.2. SYSTEMS/TECHNOLOGIES WITH MEDIUM RISK

ITEM	FUNCTION	COMMENTS
Coupled Cable Pair	Detection	Reliability of Detection is Questionable
Fiber-Optic Sensors	Detection	Reliability of Detection is Questionable
Acoustic Sensors	Detection	Reliability of Detection is Questionable
Far Infrared Video	Detection/Location	New Development
HUD	Pilot Information	Cost and Retrofit Can Be Limiting
RF with Transponder	Detection/Location	Compatibility with RF Environment
Video Image Analysis	Identification	Signal Processing Intensive
Laser	Adaptive Visual Aid	High Potential
Human Factors Lab.	Human Factors	Needs Coordination with FAA Technical Center
Alt. Lighting	Adaptive Visual Aid	High Potential
ADS	Detection/ID/Location	Requires System Analysis
Wig-Wag Lights	Visual Aid	Marginal Performance
Aircraft Simulators	Human Factors	Needs Coordination with Airlines
TCAS	Detection/ID/Location	Compatibility with RF Environment

TABLE 5.3. SYSTEMS/TECHNOLOGIES WITH HIGH RISK

ITEM	FUNCTION	COMMENTS
Piezo Film	Detection	Installation
Fiber-Optic Detectors	Detection	New Technology
Bar Code	Detection/ID	Limited Range
ASDE-3	Detection/Location	ASTA Program To Define
Holographic Signs	Adaptive Visual Aid	New Promising Technology
RF Taggants	Detection/ID	Limited Range
Fiber Optic	Detection	Installation
Acoustic	Detection	Unproved Tech. For Airport