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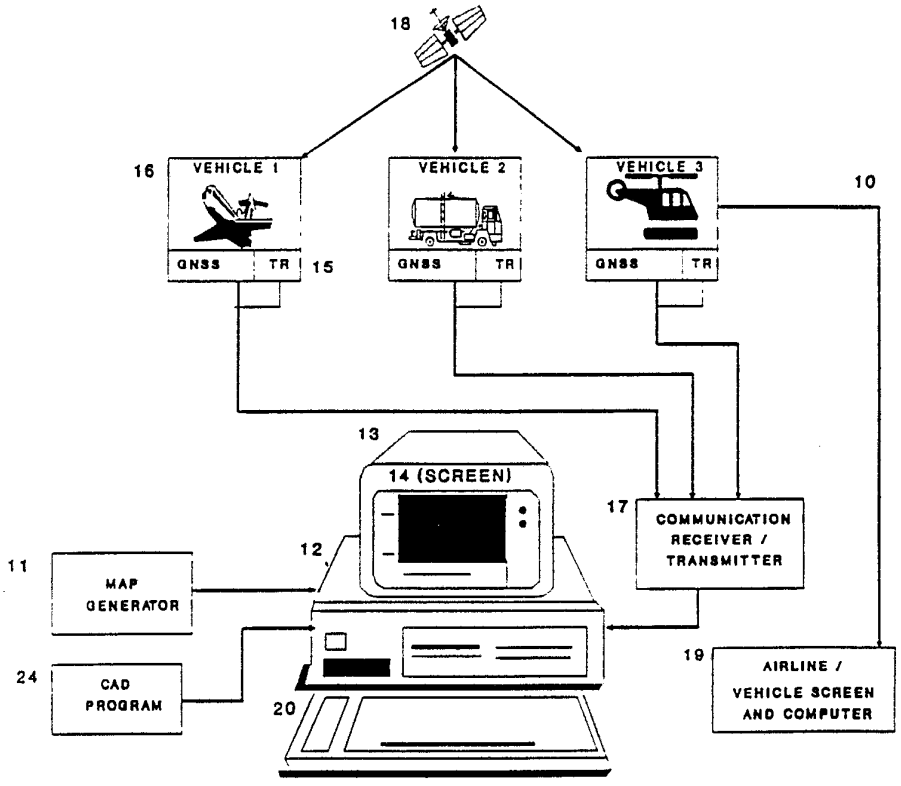
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(54) Title: AIRPORT CONTROL/MANAGEMENT SYSTEM



(57) Abstract

Image (21) on a computer screen (14) of a 3-dimensional vehicle path (23) superimposed on a 3-dimensional map (22) of a local space envelope.

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AIRPORT CONTROL/MANAGEMENT SYSTEM

BACKGROUND OF THE INVENTION

One of the major problems facing the world today is the fact that airplane travel has increased tremendously, while the airport facilities have not. Attempts to expand present airports and to build new ones have met with considerable resistance.....not only because of aesthetic factors, but also simply because there is now no inexpensive land adjacent to the large cities.

Because it appears, therefore, difficult to meet increased air traffic demands by increasing airport facilities, it is obvious that a solution to the problem may lie in allowing a given airport to make more intensive use of its facilities. The limit to such a solution lies in the necessity to maintain satisfactory safety standards. Safety plays an important role in the accuracy and limits of present day surveillance systems, as well as flight dynamics for individual aircraft. Technological advances in aircraft, such as STOL, tilt rotor, and rotary wing, will enable the Terminal Control Area (TCA) to handle increased traffic loads without increasing the surface tarmac significantly.

The present airport control systems rely heavily on a radar display screen that shows the location of aircraft in flight in a two dimensional format; the individual planes are labelled for altitude and other factors; unfortunately, much of the work involves visual observation through the control tower window and verbal communication.

Considerable work has been done recently in attempts to improve airport traffic control. The patent of MUNDRA No. 4,890,232, for instance, has to do with a visual display apparatus for showing the relationship of two separate aircraft on converging runways. The patent of

GERSTENFELD, No. 4,827,418, describes an expert system for training control operators. The patent of GRAHAM et al., No. 4,811,230, shows a flight management computer that includes an intervention system. The patent of THURMAN, No. 4,706,198, describes a computerized airspace control system invoking a master control system and regional control units. A patent to SCHWAB et al., No 4,516,125, shows apparatus for monitoring vehicle ground movement in the vicinity of an airport and involves the processing of radar return video signals. The patent of LOMAX et al., No. 4,075,666, shows a magnetic tape recorder for use in the continuous televising of air traffic control radar. The patents of VIETOR, Nos. 3,875,379; 3,868,497; and 3,758,765, have to do with terminal airways traffic control; a ground-based computer issues speed commands. The patent of MASSA, No. 3,855,571, describes an aircraft traffic control system involving a sound generator on each airplane that reaches selected microphones along its ground path, the signals thus received operating on a display panel in the form of a map. A patent of FELLMAN, No. 3,787,056, relates to a game device for simulating aircraft traffic control and teaching the rules of traffic control. The patent of KURKJIAN, No. 3,731,312, has to do with an air traffic control utilizing rotating radial signals. In all of these cases, the airport controller lacks sufficient information to handle large amounts of aircraft landing and taking off, particularly when mixed with service vehicles on the ground. A great deal of the safety of these systems depends on the visual and verbal information that the control personnel picks up and this information is subject, of course, to the fallibility of the human mind. These and other difficulties experienced with the prior art devices and systems have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a cost-effective airport control/management system for vehicles which are operating in 3-dimensional space.

Another object of this invention is the provision of a control/management system, especially for aircraft control, in which a 3-dimensional display is produced to show the information necessary to operate an airport.

A further object of the present invention is the provision of a means for handling increased traffic at an airport without loss of safety.

A still further object of the invention is the provision of a system for superimposing a 3-dimensional display of local aircraft paths on an accurately-configured map of the local space.

It is a further object of the invention to provide an airport traffic control system which will permit an increase in airport capacity and safety, while allowing the airport to remain within present territorial boundaries.

Another object of the invention is the provision of an improved surveillance system for airport arrival and departure aircraft separation.

Another object of the invention is the provision of an airport control/management system that is suitable to the task of providing for increased traffic, while maintaining safety; that will enjoy a wide and growing market acceptance with declining life cycle costs; and that will integrate easily with other parts of the air traffic control and aircraft navigation systems.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

SUMMARY OF THE INVENTION

In general, the present invention has to do with an airport control/management system which has a means for establishing a precise 3-dimensional digital map of a selected airport space envelope, the map containing global positioning system reference points. A computer with a monitor screen is provided for receiving and displaying the 3-dimensional map. Means is provided that is located on at least one vehicle in the airport space envelope to receive continuous global navigation satellite system (GNSS) signals, calculate position, velocity, heading, and time and transmitting the information to a receiver associated with the computer. Means is provided within the computer to display a 3-dimensional image corresponding to the vehicle path on the 3-dimensional map.

More specifically, the global navigational satellite system includes a constellation of space satellites and the computer contains a program for manipulating the image of the vehicle path and the map together to a desired apparent line of observation.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may be best understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

Figure 1 is a generally schematic view of an airport control/management system incorporating the principles of the present invention,

Figure 2 is a plan view of an airport with a vehicle path imposed, as it appears on a computer screen in the system,

Figure 3 is a view of the airport and vehicle path as it appears on the screen with a 20-degree viewing angle,

Figure 4 is a diagram showing the pattern generated by the vehicle in take-off mode,

Figure 5 shows a block diagram of a radio-based data link system which embodies the principles of the present invention,

Figure 6 is a plan view of an airport with a trajectory path, waypoints and monumented survey points imposed, as it appears on a computer screen in the system,

Figure 7 describes the airport terminal system hardware components which embodies the hardware principles of the present invention,

Figure 8 describes the airport terminal system software components which embodies the software principles of the present invention,

Figure 9 describes the aircraft/vehicle system's hardware components which embodies the hardware principles of the present invention,

Figure 10 describes the aircraft/vehicle system's software components which embodies the software principles of the present invention, and

Figure 11 shows aircraft in 3-D airport map. Aircraft are 3-D scaled representations of real aircraft. Aircraft are drawn into the map from a data base of various aircraft types.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to Figure 1, which best shows the general features of the invention, the airport control/management system, indicated generally by the reference numeral 10, is shown as including a map generator 11 for establishing a precise 3-dimensional digital map of a selected airport space envelope. The map contains global positioning system reference points. The system includes a computer 12 having a monitor 13 with a screen 14. The computer and screen serve to receive and display the 3-dimensional map.

A GNSS receiver 15 is located in a vehicle 16 (#1), which is located in the airport space envelope. The GNSS receiver calculates the position, velocity, time and heading, possibly using reference station corrections. These signals are transmitted to a receiver 17 which, in turn, is connected to the computer 12. The computer contains a program to use the said signals to superimpose a 3-dimensional image corresponding to the vehicle path onto the 3-dimensional map.

The GNSS receiver incorporated in the vehicles contains, in the usual way, access to space satellites 18. The computer 12 contains a computer-aided-drawing (CAD) program 24 that is capable of manipulating the image of the vehicle path and the map to a desired apparent point of observation. A secondary screen 19 may be provided at a suitable airline facility, to show the location and movement of the airline's own vehicle (#3, for instance).

Figure 2 shows the image 21 as it appears on the monitor screen 14 when the 3-dimensional map 22 of the airport (generated by the generator 11) has the path 23 of a vehicle, such as vehicle #1, imposed upon it. This is a plan view in which the airport map is shown as it appears from directly above and as the vehicle path appears from the same vantage point. The term "airport" can, of course, include not only conventional land-based airports, but also vertiports, heliports, and sea bases.

Figure 3 shows the appearance of the screen 14 when the computer aided drawing program 24 is used to rotate the image to an aspect which is 20 degrees out of the horizontal. In both Figures 2 and 3, the vehicle is shown in the taxi to take-off mode, but, of course, the appearance would be somewhat similar if it were in the landing mode.

The operation and advantages of the invention will now be readily understood in view of the above description. The method of establishment of a precise 3-dimensional digital map 22 is well-known and makes use of photogrammetry and stereoscopic digitalization techniques. The digital information contained in the map generator 11 is then applied through the computer 12 to the screen 14. At that time, the map 22 appears on the screen and the resulting image can be manipulated by use of the computer-aided drawing program 24 to show the appearance of the airport space envelope as it appears from any desired angle and at any distance. This manipulation is controlled by means of a keyboard 20, other standard input device, such as a mouse or tablet, or resident applications software.

The next step consists of receiving GNSS signals, using an antenna designed for this purpose. The on-board receiver on the aircraft 16 performs the necessary calculations and then transmits the results using a

transmitter 15 within the vehicle. The equipment makes use of satellites 18 whose position relative to the earth's center of mass is precisely known. The transmitter 15 sends information as to the aircraft's location, speed, heading, identification and time of transmission to the receiver 17 and this is presented to the computer 12 for display on the screen 14. The information thus transmitted generates an image 21 on the screen which represents a three-dimensional picture of the vehicle path 23 superimposed on the map 22. The image 21 thus produced can be rotated by the CAD program 24 to any desired angle and zoomed to enlarge or decrease the size.

Figure 2 shows the appearance of the image 21 in plan, i.e., as the airport and aircraft path appear when viewed from directly above. Figure 3 shows the image when the observation angle is 20 degrees above the horizontal. It can be seen, then, that an accurate visualization of the vehicle's progress is made possible by selecting various angles of view, as desired. For instance, the chart of Figure 4 shows a typical elevation profile of an aircraft as it moves about the airport preparatory to taking off and then as it takes off. The image 21 can, of course, be transmitted and displayed on other screens; for instance, the screen 19 is located in the facilities of an airline whose vehicle #3 is within the airport space envelope. Since that airline may only be interested in its own vehicle, their screen image may show only that vehicle, or, if desired, may show the same complete image (with other vehicles that is shown on the main screen 14). Similarly, the image 21 can also be displayed on a screen in the aircraft or other airport vehicle. Again, the screen image may show only that vehicle or, if desired, the same or another image that is shown on the main screen 14.

It can be seen, then, that the present inventive system provides an integrated airport planning and design tool. It incorporates available technologies of the type that will play an important future role in aviation navigation and air traffic control.

Air transportation is expected to grow at a large rate in the next few years. The predicted growth will place a substantial load on existing airports. Present airports will need to be modernized to support such growth. Building new runways and buildings is expensive and sometime difficult politically. A better method of improving airport capacity and safety may be from improved automation and modernization. Automation and modernization can be a viable method of increasing capacity and safety, while the airports remain within present territorial boundaries.

The present invention, therefore, serves to satisfy three primary objectives. The three objectives are: (a) suitability for the task, (b) a wide market acceptance with declining life cycle costs, and (c) ability to integrate easily with other parts of the air traffic control and aircraft navigation systems.

In a practical embodiment of the invention, the computer used was a personal computer with 3-D graphics. It was based on a 386 chip operating at 33 MHZ with a 12 MB, 80 NS RAM and 387 co-processor. The global position system was the NAVSTAR GPS utilizing earth centered, earth fix (ECEF) coordinates and using the ECEF world geological survey (WGS-84) which was ellipsoid-adjusted for geoid separation. The separation was -28.3 meters mean sea level (MSL) elevation at Manchester, N.H. and used in the 3-D map converted between latitude/longitude and N.H. state plane and other coordinates. The computer used the MSDOS operating system or SCO XENIX OS operating system with

modem capability.

In addition to the basic system described above, a great many other features can be added to the system of 3-D airport maps for air traffic control and navigation.

Another feature of the system involves having the airport map arranged in layers for target sorting and tracking. Each layer could be specified for particular function such as air traffic control, airline or airport operations. The system operator could select one or more layers to be displayed. In this way, only information relevant to his present function would be displayed.

Another feature of the system involves the use of precise multi-monumented survey points in airport area for local coordinate conversions and real time map displays.

Another feature of the system is the concept of forbidden zones (areas off limits) based on latest notice to airmen information (notams). These zones are created in the map data base, then used in navigational algorithms. Warnings are generated to the pilot and/or the air traffic controller when the airplane is in or approaching a zone. A forbidden zone can be around two potentially colliding aircraft.

Another feature of the system is the use of a digital data link for automatic dependent surveillance (ADS-radar free surveillance) in the terminal controller area. The system preferably uses X.25 carrier sense multiple access (CSMA) digital communications using frequency division multiplexing (FDM). This technique uses the existing VHF aeronautical spectrum or other available RF spectrum.

The data radios used in the practical embodiment of the invention featured 25 kilohertz channel spacing versus

the 50 kilohertz spacing still in use today. Recently the Federal Communication Commission (FCC) delayed the date when 25 KHz channel spacing will be required for all aviation users until 1997. The aeronautical VHF band operates at frequencies from 118 MHz to 136.975 MHz, giving a total of 760 channels based on 25 KHz channel spacing. Since spectrum is not infinite, sensible use is necessary. The following model is used to provide insight into possible system capacity and operational tradeoffs. The model uses data for the New York Metroplex and southern New Hampshire area.

DATA LINK ASSUMPTIONS

1. Traffic control area air and ground targets transmit position to tower air traffic controller.

2. The data link is full duplex over two channels, to and from the aircraft and control tower air traffic control facility.

3. Non-moving aircraft will report positions only once per minute or upon tower interrogation.

4. Moving aircraft will broadcast position once per second on approach and departure otherwise every two seconds or upon interrogation.

5. Use of voice communications will be minimized and restricted to use on selected channels.

6. Radio frequency transmission rate is typically 4800 baud.

7. Carrier Sense Multiple Access X.25 transmission connection, error detection overhead and packet collisions reduce effective RF bw to 1200 baud.

8. Frequency agile (scanning) radios are used with 760 channels.

9. Selected channels are dedicated to tower broadcasts (ATIS, interrogation, differential corrections, etc.).

10. During data collisions, the "capture effect" will allow the strongest transmission to get through, naturally filtering out unwanted signals from aircraft far outside the traffic control area.

11. If a particular channel is saturated, the ADS message handler automatically retransmits on another available channel.

12. Integrity is handled in the GPS receiver with one of the developing techniques.

13. Time of transmission.

Each aircraft broadcasts its ADS message as defined above. The message consists of the following data:

ATC system is based on ECEF positions, only maps are in surface coordinates.

TYPICAL MESSAGE

ID#	8 Characters
Current Position:	
ECEF X Position (M)	10 Characters
ECEF Y Position (M)	10 Characters
ECEF Z Position (M)	10 Characters
ECEF X2 Position (M)	2 Characters *
ECEF Y2 Position (M)	2 Characters *
ECEF Z2 Position (M)	2 Characters *
ECEF X3 Position (M)	2 Characters *
ECEF Y3 Position (M)	2 Characters *
ECEF Z3 Position (M)	2 Characters *
ECEF X Velocity (M/S)	4 Characters
ECEF Y Velocity (M/S)	4 Characters
ECEF Z Velocity (M/S)	4 Characters
Next waypoint (where headed information):	
ECEF X	10 Characters
ECEF Y	10 Characters
ECEF Z	10 Characters
Time	6 Characters (hhmmss)
Total Characters/Message	98 Characters

The asterisks identify optional fields for designating and determining vehicle attitude in 3-D digital map data base.

Figure 5 shows a block diagram of a radio-based data link system which embodies the principles of the present invention. As described above, in this bi-directional communication system, each airplane tries to get a connection on a particular channel, using the X.25 protocol. If an airplane is unable to use that channel within a predefined period of time, the airplane tries

another randomly selected channel (FDM). This technique maximizes use of the available radio frequency spectrum and automatically adjusts to traffic load.

Another feature of the system is use of carrier sense multiple access bi-directional data link for tower to aircraft communication.

Another feature of the system is use of earth centered, earth fixed (ECEF) navigation on the airport surface, and in the terminal airspace.

Another feature of the system is use of three GPS antennas to determine aircraft attitude. Attitude of aircraft is then used to draw the aircraft in the 3-D digital map with the proper attitude. Antennas are placed at three known positions on the aircraft. The GPS positions are then used as handles to draw the aircraft into the 3-D map.

Another feature of the system is that the data link supports three ECEF positions in the data message, so the airplane can be shown at the proper attitude in the 3-D airport map presentation. Therefore, this information is provided in the data link message.

Another feature of the system is automatic dependent surveillance (ADS) transmission broadcast rate which is programmed to the phase of flight. Thus, the data transfer rate varies, depending on the data rate needed for the airplane's present activity. For example, an aircraft which is not moving or is not occupied would transmit once every 60 seconds, an aircraft which is taxiing would transmit every 2 seconds, and an aircraft which is on approach or departure would transmit every second. This maximizes available bandwidth of aeronautical spectrum because each airplane would transmit at a minimum rate

which is required at that phase of its flight. Reporting rates may be easily modified as conditions warrant.

Another feature of the system is the construction of a position keyed data base which maintains the last position an aircraft reported. When a plane taxis to a parking location, the data base maintains the plane's position when and after the aircraft is turned off. When the plane is used again and starts to move, the data base is updated with new position data. In this manner, the data base will be self loading and will eventually contain all aircraft in the airport. This concept is extensible to airport surface vehicles such as fuel trucks and buses.

Another feature of the system is the use of precise velocity and acceleration information, derivable from GNSS navigation and position information, as inputs into collision projection algorithms based on the earth centered, earth fixed reference.

Another feature of the system is the use of a multi-windowed display showing different sections or views of the airport in each window.

Another feature of the system is the ability to use map layers and zones of the map to segregate information into various air traffic controllers' stations.

Another feature of the system is the use of a position keyed aircraft data base to automatically filter aircraft. This would be performed using GPS position, the ADS data link, and the ground computer data base.

Another feature of the system is man-machine interface capability in which the controller defines a departure and/or approach trajectory (air and surface) using the data entry device and 3-D airport map, or calls up a previously

defined trajectory. The path contains waypoints, notam data and forbidden zone information. The information is drawn into the map and then waypoints are passed to the aircraft as part of ATC clearance. The air traffic control system matches the present position and the next on-board waypoint with stored trajectory data in air traffic control computer. An alarm is sounded if a preset threshold or deviation is exceeded, meaning the aircraft is off course.

Further disclosure: FIGS. 6-10.

Figure 6 shows the appearance of the screen 14 when a trajectory path 24, waypoints 25 and monumented survey points 26 are imposed on the digital map. In Figure 6, the trajectory path is shown for a taxiing maneuver, but, of course, the appearance would be somewhat similar for other taxi maneuvers as well as take off and landing trajectories. Figure 6 also shows the appearance of the screen 14 when a forbidden zone 27 is imposed on the digital map.

Figure 7 shows the major hardware components of the airport terminal control system. For each vehicle 28 equipped with a GNSS receiver and transmitter, a GNSS message is transmitted via the vehicle's radio equipment 29 through the communication interface 30 to the ATC computer 32. The signals may include differential corrections broadcast by a differential base station 31. The computer operator has access to a variety of data entry devices 33 including, but not limited to, a keyboard 35, mouse, spaceball or trackball 36 to control the presentation on the computer display screen 34.

Figure 8 shows the major software components of the airport terminal control system. The GNSS signals broadcast by the vehicles 37 and the differential corrections determined by the differential GNSS software 39 are processed by the Real Time Communication Handler 38 and sent to the ATC Processor 40. The ATC Processor uses the GNSS data to perform the following processing functions listed under item 41: projections, coordinate conversions, zone detection, layer filter, view control, alarm control and display updates. The ATC Processor software 40 also receives inputs from the Controller Interface 43 software. The Controller Interface uses the data received by the controller's inputs 44 to compose ATC commands which are sent to the ATC Processor 40 for processing. Commands affecting the presentation on the computer display screen 34 are sent by either the ATC Processor 40 or Controller Interface 43 to the Graphical Control 42 software. Both the ATC Processor and Graphical Control 42 software use the Monumentation, NOTAMS, Trajectories, Aircraft/Vehicle, Airport Map, ATIS Interface and Airport Status data bases 45 to manipulate the presentation on the computer display screen 14.

Figure 9 shows the major hardware components of the aircraft-vehicle system. The Aircraft Computer 52 receives GNSS data from the on-board GNSS receiver 51 and, optionally, from other vehicles 48 through its radio 49 and communications interface device 50. Messages are received from the ATC Tower 47 through the same communications path. Differential correction broadcasts are received through the radio equipment 49 and communication interface 50 to the GNSS receiver 51 where they are processed internally and then passed to the Aircraft Computer 52. The operator has access to the on-board data entry and display devices 53 including, but not limited to, a keypad 55, mouse and a display screen 54.

Figure 10 shows the major software components of the aircraft-vehicle system. The GNSS signals broadcast by other vehicles 57 (optional), the differential correction broadcasts 58 and ATC messages 59 sent from the tower or remote station are processed by the Real Time Communication Handler 59 and sent to the Aircraft Processor 61. GNSS messages from the on-board GNSS receiver 60 are also received by the Aircraft Processor 61. The Aircraft Processor uses both the remote and on-board GNSS data to perform the following processing functions listed under item 62: projections, coordinate conversions, zone detection, layer filter, view control, alarm control and display updates. ATC commands are processed upon receipt from the Real Time Communication Handler 59. Display updates to the airline/vehicle screen 19 are passed from the Aircraft Processor 61 software to the Graphical Control 60 software. Both the Aircraft Processor 61 and Graphical Control 63 software use the Monumentation, NOTAMS, Trajectories, Aircraft/Vehicle, Airport Map, ATIS Interface and Airport Status data bases 64 to manipulate the presentation on the computer display screen 19.

Figure 11 shows aircraft in 3-D airport map. Aircraft are 3-D scaled representations of real aircraft. Aircraft are drawn into the map from a data base of various aircraft types.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

CLAIMS

1. Airport control/management system, comprising:

(a) means establishing a precise 3-dimensional digital map of a selected airport space envelope, the map containing global positioning system reference points,

(b) a computer with a monitor screen for receiving and displaying the 3-dimensional map,

(c) means located on at least one vehicle in the airport space envelope to transmit continuous GNSS-based reports,

(d) a receiver associated with the computer to receive the said transmitted reports from the vehicle, and

(e) means associated with the computer and using the said signals to superimpose a 3-dimensional image corresponding to the vehicle path onto the 3-dimensional map.

2. Airport control/management system as recited in Claim 1, wherein the GNSS includes space satellites.

3. Airport control/management system as recited in Claim 1, wherein the computer contains a program for 3-dimensional manipulation of the image of the vehicle path and the map to a desired apparent line of observation.

4. Airport control/management system, comprising the steps of:

(a) preparing a three-dimensional digital map of an airport space envelope,

(b) applying the digital map to the monitor screen of a computer,

(c) receiving GNSS signals and calculating position, velocity, and heading information, then transmitting data to a computer, and

(d) applying the GNSS-based information to the digital map on the screen to generate a three-dimensional image on the screen of the positioning signal on the map.

5. Airport control/management system as recited in Claim 4, including providing the computer with a computer-aided drawing program or equivalent software capable of permitting an operator to select the apparent direction that the image is viewed.

6. Airport control/management system as recited in Claim 4, including transmitting the GNSS-based information from the aircraft, and determining the aircraft position from an accurately-located space satellite.

7. Airport control/management system as recited in Claim 4, including generating the said map by using aerial photogrammetry and stereoscopic digitalization techniques.

8. Airport control/management system as recited in Claim 4, wherein the vehicle transmitted signal includes identification, position, speed, heading, and time information.

9. Airport control/management system as recited in Claim 4, including receiving the said signal and displaying it on the 3-dimensional map as a symbol representing the vehicle position.

10. Vehicle traffic control/management system, comprising:

(a) means establishing a precise 3-dimensional digital map of a selected space envelope, the map containing global positioning system reference points,

(b) a computer with a monitor screen for receiving and displaying the 3-dimensional map,

(c) means located on at least one vehicle in the space envelope continuously to transmit GNSS-based signals, and

(d) a receiver associated with the computer and using the said signals to superimpose a 3-dimensional image corresponding to the vehicle path on the 3-dimensional map.

11. Vehicle traffic control/management system as recited in Claim 10, wherein the GNSS includes space satellites.

12. Vehicle traffic control/management system as recited in Claim 10, wherein the computer contains a program for manipulating the image of the vehicle path and the map to a desired apparent position of observation.

13. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system involves having the airport map arranged in layers for target sorting and tracking. Each layer could be specified for particular function such as air traffic control phase of flight, NOTAMS, forbidden zone, airline or airport operations. The system operator could select one or more layers to be displayed. In this way, only information relevant to his present function would be displayed.

14. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system involves the use of precise multi-monumented survey points in airport area for local coordinate conversions and real time map displays.

15. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the concept of forbidden zones (areas off limits) based on latest notice to airmen information (notams). These zones are created in map data base, then used in navigational algorithms. Warnings are generated to the pilot and/or the air traffic controller when the airplane is in or approaching a zone. A forbidden zone can be around two potentially colliding aircraft.

16. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the use of X.25 digital data link for automatic dependent surveillance (radar free surveillance) in the terminal controller area. The system preferably uses X.25 carrier sense multiple access (CSMA) digital communications using frequency division multiplexing (FDM). This technique uses the existing VHF aeronautical spectrum or other available RF spectrum.

17. A vehicle traffic control/management system as recited in Claim 1, wherein the data radios used in the tests featured 25 kilohertz channel spacing versus the 50 kilohertz spacing still in use today; (recently the Federal Communication Commission (FCC) delayed the date when 25 KHz channel spacing will be required for all aviation users until 1997; the aeronautical VHF band operates at frequencies from 118 MHz to 136.975 MHz, giving a total of 760 channels based on 25 KHz channel spacing; since spectrum is not infinite, sensible use is necessary); the following model is used to provide insight into possible

system capacity and operational tradeoffs; the model uses data for the New York Metroplex and southern New Hampshire area; DATA LINK ASSUMPTIONS:

a. traffic control area air and ground targets transmit position to tower air traffic controller;

b. the data link is full duplex over two channels, to and from the aircraft and control tower air traffic control facility;

c. non-moving aircraft will report positions only once per minute or upon tower interrogation.

d. moving aircraft will broadcast position once per second on approach and departure otherwise every two seconds or upon interrogation.

e. use of voice communications will be minimized and restricted to use on selected channels.

f. radio frequency transmission rate is 4800 baud.

g. carrier Sense Multiple Access X.25 transmission connection, error detection overhead and packet collisions reduce effective RF bw to 1200 baud.

h. frequency agile (scanning) radios are used with 760 channels.

i. selected channels are dedicated to tower broadcasts (ATIS, interrogation, differential corrections, etc.).

j. during data collisions, the capture effect will allow the strongest transmission to get through, naturally filtering out unwanted signals from aircraft far outside the traffic control area.

k. if a particular channel is saturated, the ADS message handler automatically retransmits on another available channel.

l. integrity is handled in the GPS receiver with one of the developing techniques.

m. time of transmission.

Each aircraft broadcasts its ADS message as defined above. The message consists of the following data: ATC system is based on ECEF positions, only maps are in surface coordinates; TYPICAL MESSAGE:

ID#	8 Characters
Current Position:	
ECEF X Position (M)	10 Characters
ECEF Y Position (M)	10 Characters
ECEF Z Position (M)	10 Characters
ECEF X2 Position (M)	2 Characters *
ECEF Y2 Position (M)	2 Characters *
ECEF Z2 Position (M)	2 Characters *
ECEF X3 Position (M)	2 Characters *
ECEF Y3 Position (M)	2 Characters *
ECEF Z3 Position (M)	2 Characters *
ECEF X Velocity (M/S)	4 Characters
ECEF Y Velocity (M/S)	4 Characters
ECEF Z Velocity (M/S)	4 Characters
Next waypoint (where headed information):	
ECEF X	10 Characters
ECEF Y	10 Characters
ECEF Z	10 Characters
Time	6 Characters
Total Characters/Message	98 Characters

Wherein the asterisks identify optional fields for designating and determining vehicle attitude in 3-D digital map data base.

18. A vehicle traffic control/management system as recited in Claim 1, wherein a radio-based data link system as described above, in this bi-directional communication system, each airplane tries to get a connection on a particular channel, using the X.25 protocol. If an airplane is unable to use that channel within a predefined period of time, the airplane tries another randomly selected channel (FDM). This technique maximizes use of the available radio frequency spectrum and automatically adjusts to traffic load.

19. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is use of carrier sense multiple access bi-directional data link for tower to aircraft communication.

20. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is use of earth center, earth fixed (ECEF) navigation on the airport surface and in the terminal airspace.

21. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is use of three GPS antennas to determine aircraft attitude. Attitude of aircraft is then used to draw aircraft in 3-D digital map with proper attitude. Antennas are placed at three known positions on the aircraft. The GPS positions are then used as graphical "handles" to draw the aircraft into the 3-D map.

22. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is that the data link supports three ECEF positions in data message, so the airplane can be shown at proper attitude in the 3-D airport map presentation. Therefore, this information is provided in data link message.

23. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is automatic dependent surveillance (ADS) transmission broadcast rate which is programmed to the phase of flight. Thus, the data transfer rate varies, depending on the data rate needed for the airplane's present activity. For example, an aircraft which is not moving or is not occupied would transmit once every 60 seconds, an aircraft which is taxiing would transmit every 2 seconds, and an aircraft which is on approach or departure would transmit every second. This maximizes available bandwidth of aeronautical spectrum, because each airplane would transmit at a minimum

rate which is required at that phase of its flight.

24. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the construction of a position keyed data base which maintains the last position an aircraft reported. When a plane taxis to a parking location, the data base maintains the plane's position when and after the aircraft is turned off. When the plane is used again and starts to move, the data base is updated with new data. In this manner, the data base will be self loading and will eventually contain all aircraft in the airport.

25. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the use of precise velocity and acceleration information, derivable from GNSS navigation and position information, as inputs into collision projection algorithms based on the earth centered, earth fixed reference.

26. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the use of a multi-windowed display showing different sections or views of the airport in each window.

27. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the ability to use map layers and zones of the map to segregate information into various air traffic controllers' stations.

28. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is the use of a position keyed aircraft data base to automatically filter aircraft. This would be performed using GPS position, the ADS data link, and the ground computer data base.

29. A vehicle traffic control/management system as recited in Claim 1, wherein another feature of the system is man-machine interface capability in which the controller defines a departure and/or approach trajectory (air and surface) using the data entry device and 3-D airport map, or calls up a previously defined trajectory. The path contains waypoints, notam data and forbidden zone information. The information is drawn into the map and then waypoints are passed to the aircraft as part of ATC clearance. The air traffic control system matches the present position and the next on-board waypoint with stored trajectory data in air traffic control computer. An alarm is sounded if a preset threshold or deviation is exceeded, meaning the aircraft is off course.

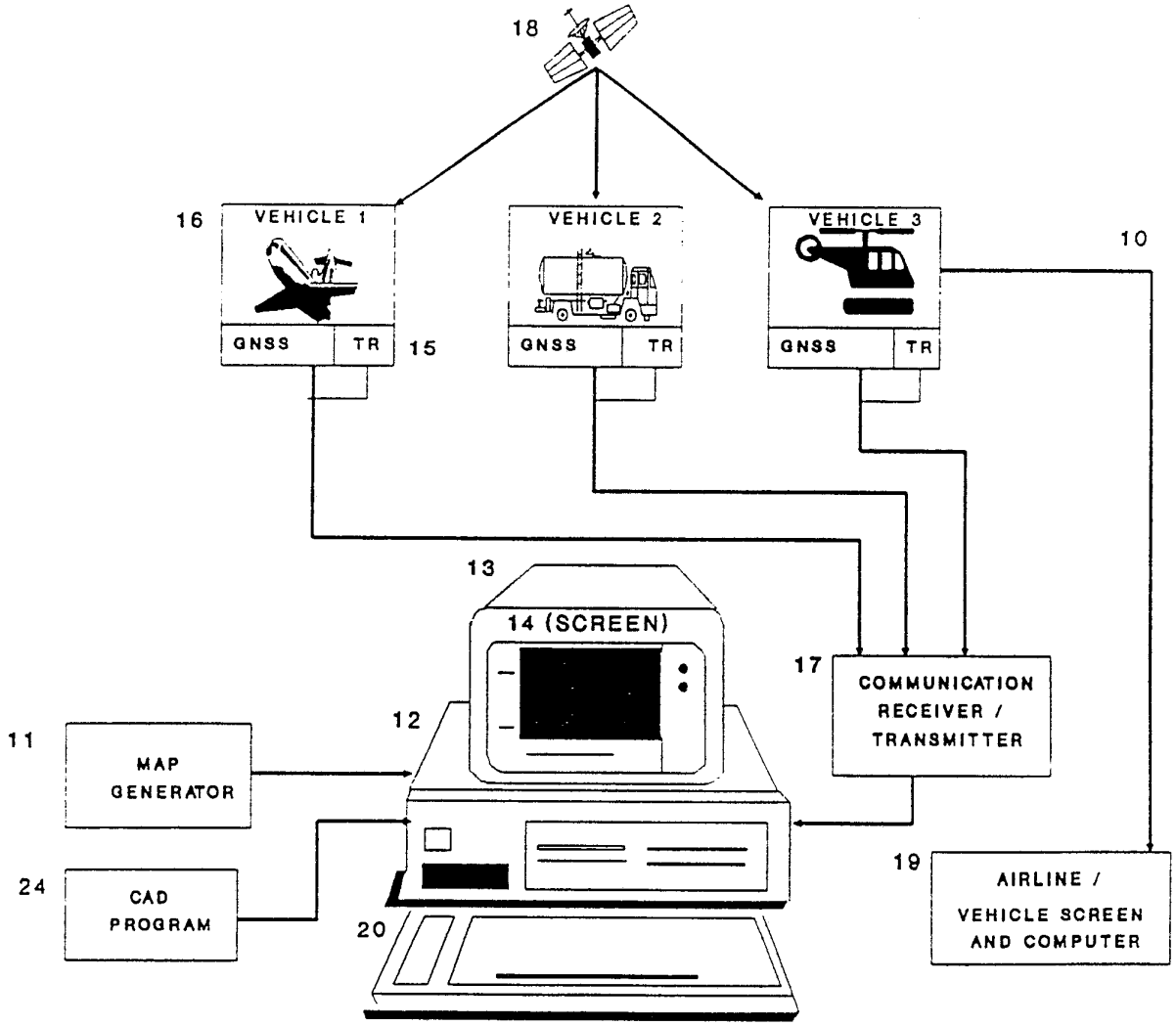

18
16
VEHICLE 1
VEHICLE 2
VEHICLE 3
10
GNSS
TR
15
GNSS
TR
GNSS
TR
13
14 (SCREEN)
17
COMMUNICATION RECEIVER / TRANSMITTER
12
11
MAP GENERATOR
24
CAD PROGRAM
20
19
AIRLINE / VEHICLE SCREEN AND COMPUTER

FIG. 1

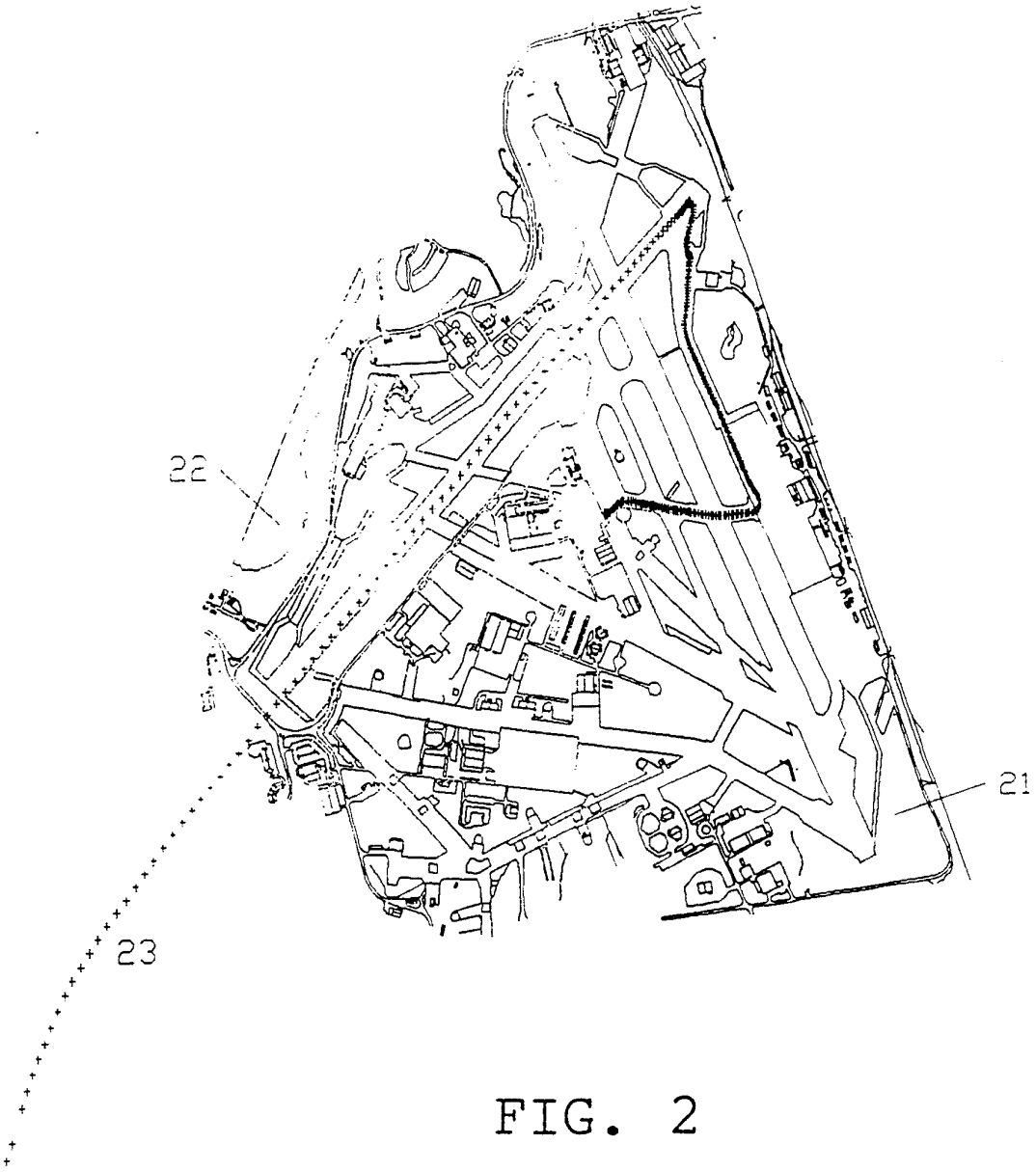


FIG. 2

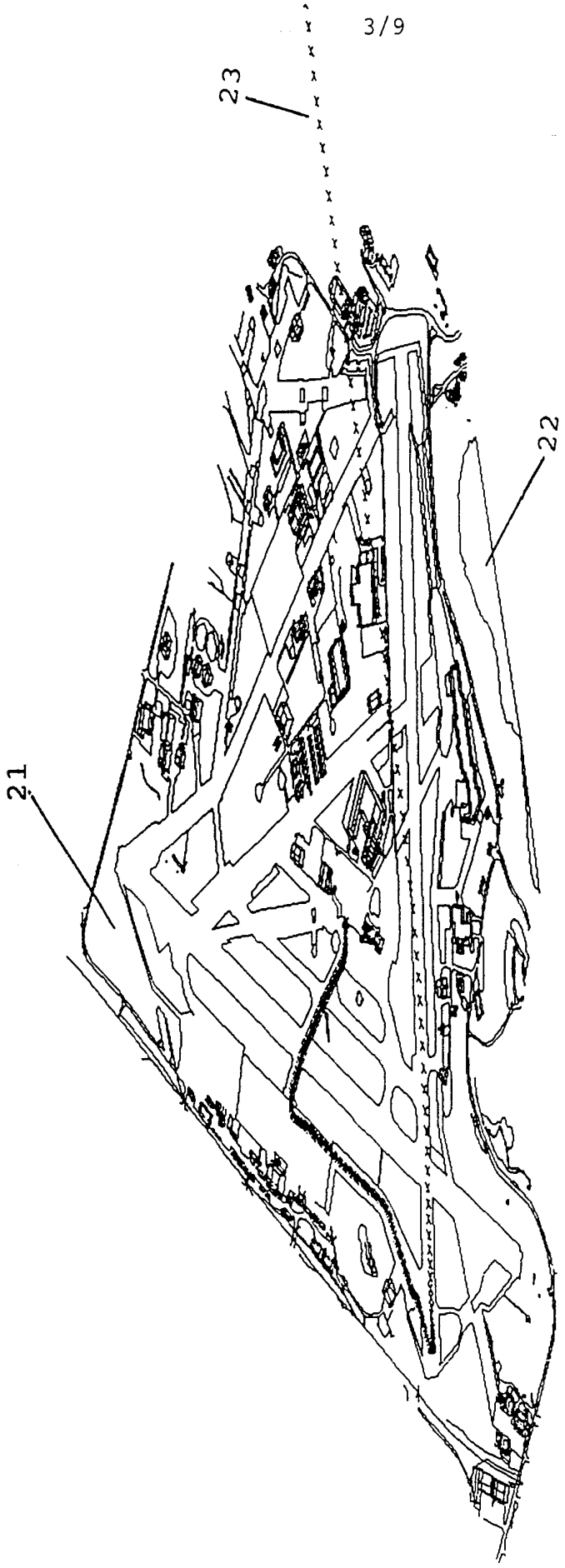


FIG. 3

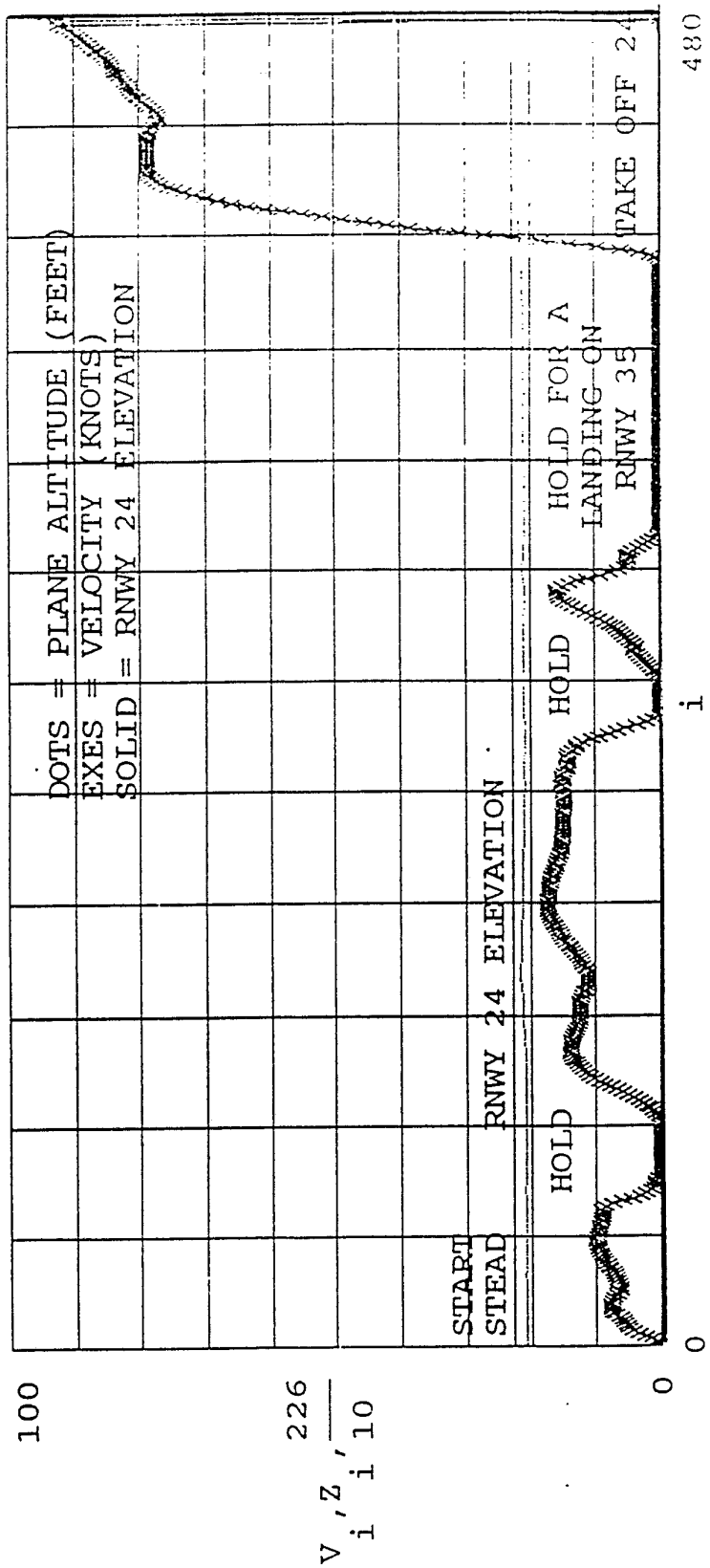


FIG. 4

TAXI FROM STEAD TO 24 FOR TAKE OFF
VELOCITY (KNOTS) & ALTITUDE/10 (FEET) VERSUS TIME

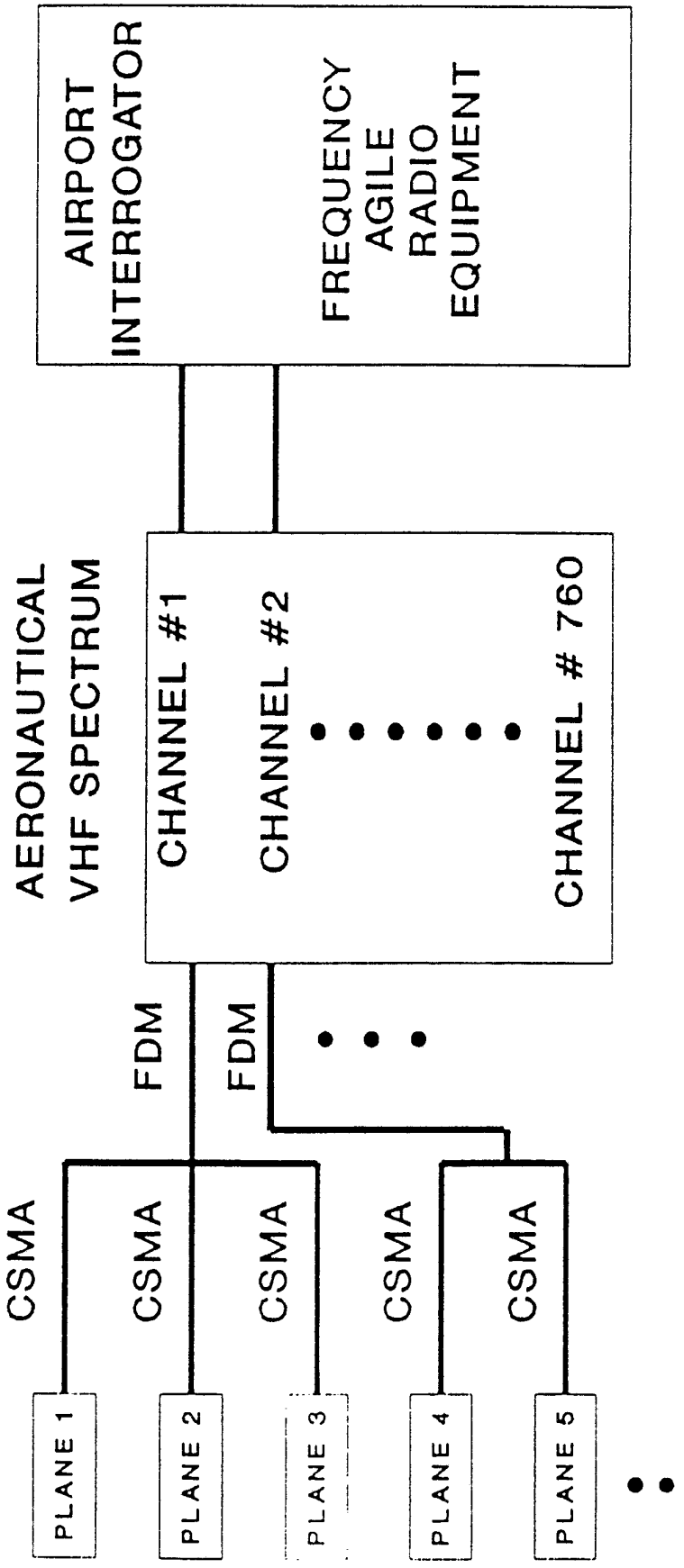

AIRPORT INTERROGATOR
FREQUENCY AGILE RADIO EQUIPMENT
AERONAUTICAL VHF SPECTRUM
CHANNEL #1
CHANNEL #2
CHANNEL # 760
FDM
FDM
CSMA
CSMA
CSMA
CSMA
CSMA
PLANE 1
PLANE 2
PLANE 3
PLANE 4
PLANE 5

FIG. 5

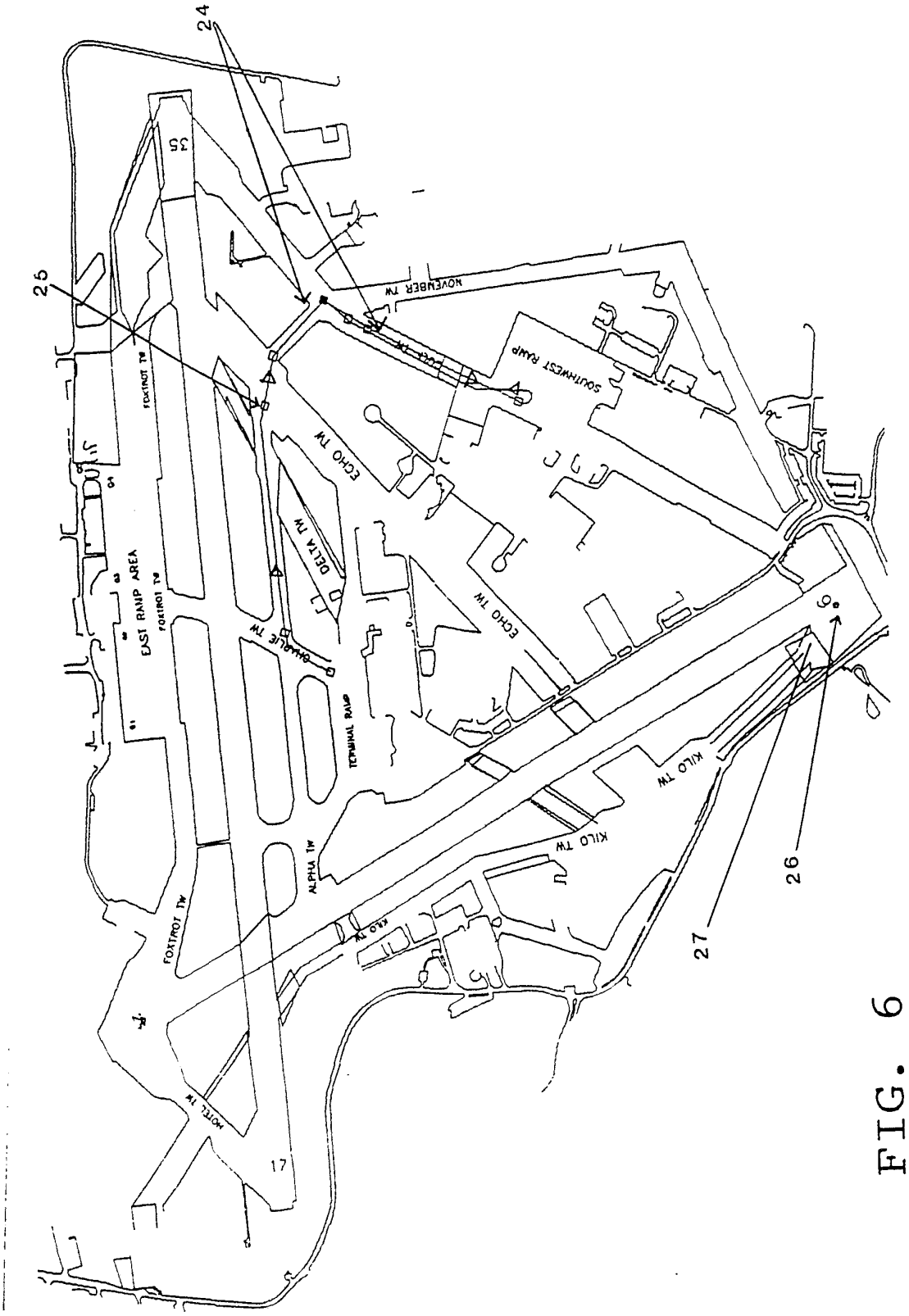

24
25
35
NOVEMBER TW
SOUTHWEST RAMP
ECHO TW
DELTA TW
FOXTROT TW
EAST RAMP AREA
TERMINAL RAMP
ALPHA TW
KILO TW
MOTEL TW
17
26
27

FIG. 6

HARDWARE SYSTEM COMPONENTS

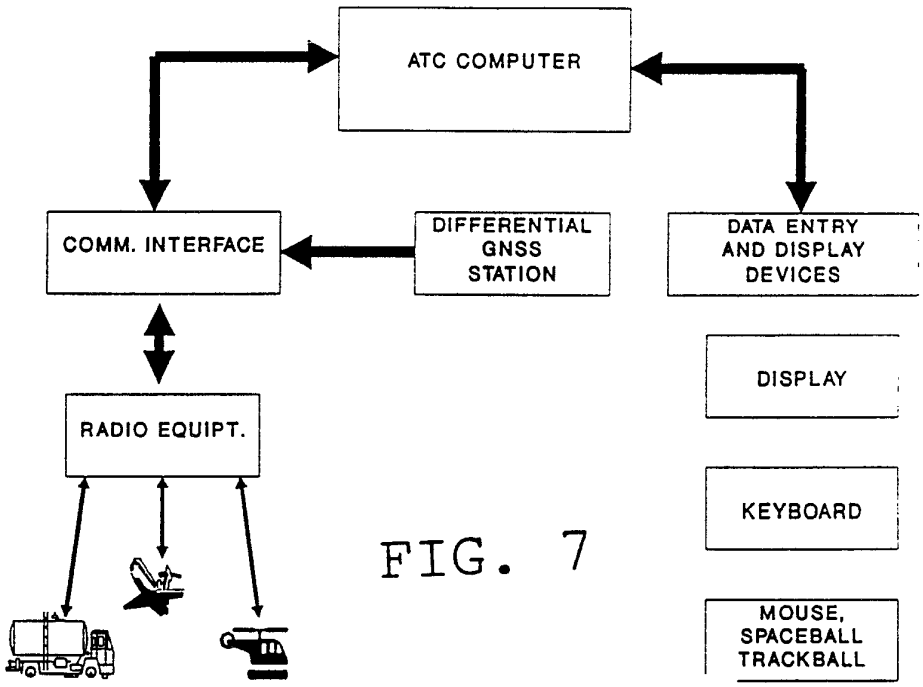


FIG. 7

SOFTWARE SYSTEM COMPONENTS

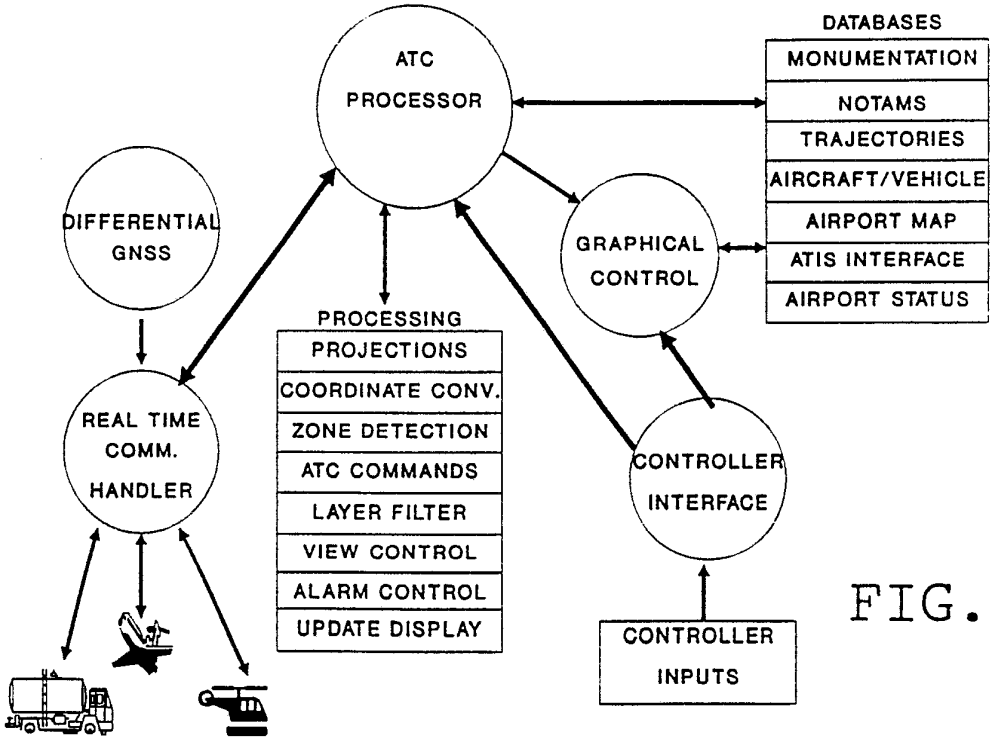


FIG. 8

AIRCRAFT - VEHICLE HARDWARE SYSTEM COMPONENTS

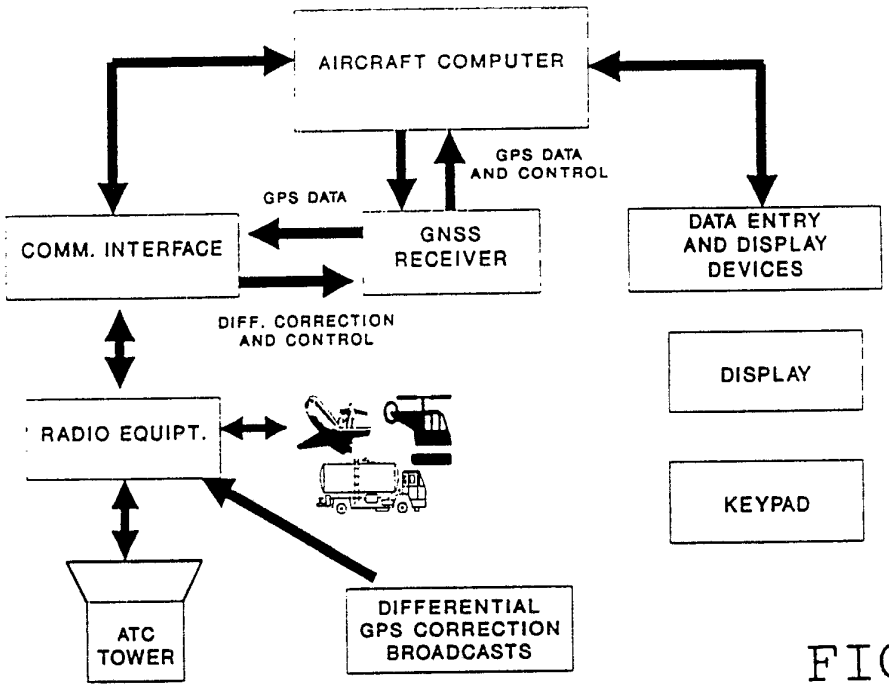


FIG. 9

AIRCRAFT - VEHICLE SOFTWARE COMPONENTS

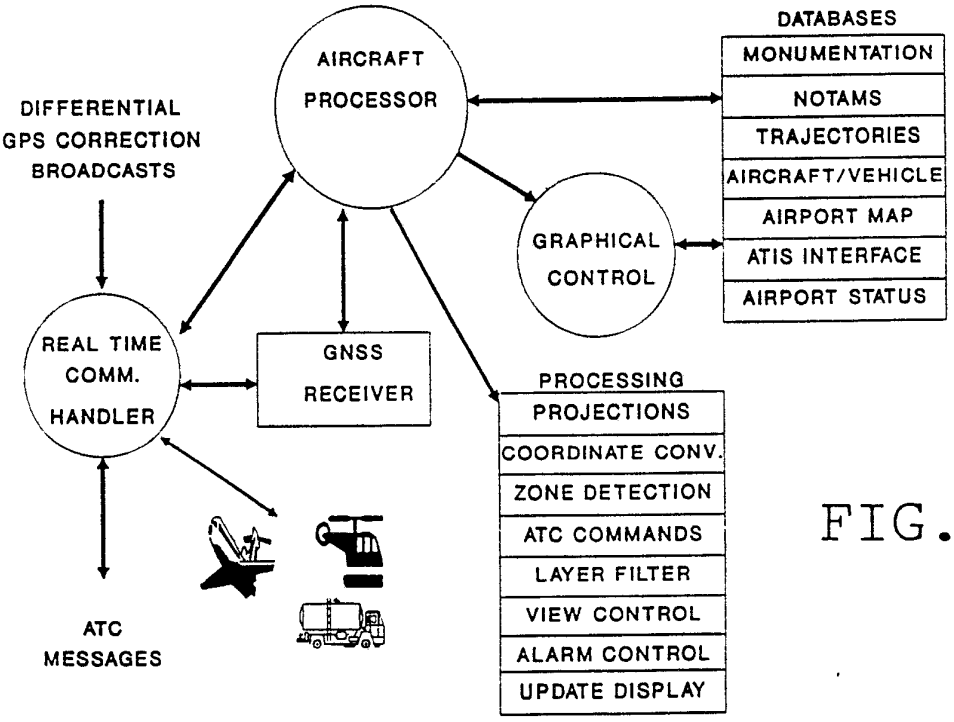
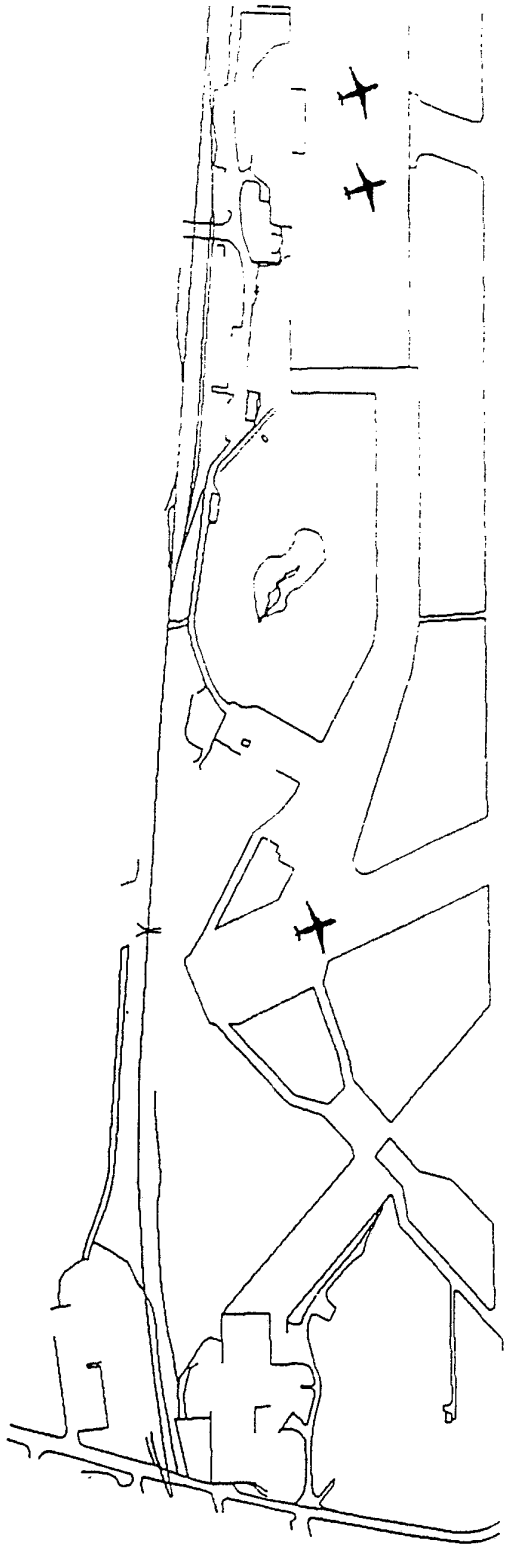


FIG. 10

FIG. 11



INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/07575

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5) G06F 15/48
U.S. CL 364/439, 461; 342/36, 455, 456; 340/990 ; 73/1785

II FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	364/427,428,439,449,460,461 342/36, 38,454,455,456 340/942, 951, 990,091,902, 995; 73/178R, 178T

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	US,A 4,660,037 (Nakamura) 21 April 1987 see Figs. 1-2 and column 4, lines 9-44	1-12,18-20 & 25-26
Y	US,A 3,665,403 (Meilander) 6 June 1972 see Fig. 14 and columns 17-18	1-12, 20& 25
P,Y	US,A 5,025,382 (Artz) 18 June 1991 see Fig. 1 (Items 20 and 22)	18-19
A	US, A 4,661,811 (Gray et al) 28 April 1987	13
Y	US, A 4,890,233 (Ando et al) 26 December 1989 see Fig 1 (Item 4)	1-12
P,A	US,A 4,975,696 (Salter, Jr. et al) 4 December 1990	1-12
A	US, A 4,516,125 (Schwab et al) 7 May 1985	15

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

15 January 1992

Date of Mailing of this International Search Report

29 JAN 1992

International Searching Authority

ISA/US

Signature of Authorized Officer

for Gary Chin

NGUYEN NGOC-BO
INTERNATIONAL DIVISION

Form PCT/ISA/210 (second sheet) (Rev.11-87)