Rec. #65996

AA

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF MICHIGAN
SOUTHERN DIVISION

FILED
JUN - 8 2007
CLERK'S OFFICE
U.S. DISTRICT COURT
ANN ARBOR, MI

DENSO CORPORATION
and
DENSO INTERNATIONAL AMERICA, INC.

Plaintiffs,

v.

HONEYWELL INTERNATIONAL, INC.,

Defendant.

______________________________/

Civil Action No. 07-12462

AVERN COHN

MAGISTRATE JUDGE WHALEN

COMPLAINT FOR DECLARATORY JUDGMENT

NOW COME the Plaintiffs, DENSO CORPORATION (hereinafter sometimes referred to as "DENSO") and DENSO INTERNATIONAL AMERICA, INC. (hereinafter sometimes referred to as "DENSO AMERICA"), by its attorneys HARNESS, DICKEY & PIERCE, PLC, and for its Complaint for a declaratory judgment against HONEYWELL INTERNATIONAL, INC. (hereinafter sometimes referred to as "HONEYWELL"), states as follows:

NATURE OF THE ACTION

1. This is an action under the Patent Laws of the United States, Title 35 United States Code, as amended, and the Declaratory Judgment Act, Title 28 United States Code § 2201, arising from a case of actual controversy between Plaintiffs DENSO and DENSO AMERICA and Defendant HONEYWELL.

PARTIES

2. DENSO CORPORATION is a Japanese corporation with its principal place of business in Kariya, Japan.

3. DENSO INTERNATIONAL AMERICA, INC. is a Delaware corporation with its principal place of business in Southfield, Michigan.

4. HONEYWELL INTERNATIONAL INC. is a Delaware corporation with a principal place of business in Morris Township, New Jersey. HONEYWELL INTERNATIONAL INC. is registered to do business in the State of Michigan under Michigan Corporate Identification Number 626822. HONEYWELL INTERNATIONAL INC.'s resident agent in Michigan is CSC-LAWYERS INCORPORATING SERVICE COMPANY, 601 Abbott Road, East Lansing, MI 48823. HONEYWELL INTERNATIONAL INC. is doing business within Michigan, including within the Eastern District of Michigan.

JURISDICTION AND VENUE

5. This Court has subject matter jurisdiction over Plaintiffs' complaint for declaratory judgment pursuant to Title 28 United States Code §§ 1331 and 1338(a), 2201 and 2202.

6. Personal jurisdiction over Defendant is proper in this district pursuant to the laws of the State of Michigan effecting jurisdiction upon Defendant based upon Defendant's contacts with this jurisdiction.

7. Venue is proper in this judicial district under Title 28 United States Code § 1391(c).

BACKGROUND

8. As recorded in the United States Patent and Trademark office, HONEYWELL is the owner of U.S. Patents Nos. 5,923,286 ("the '286 Patent"); 6,289,277 ("the '277 Patent"); 6,308,132 ("the '132 Patent"); 6,664,945 ("the '945 Patent"); 6,691,030 ("the '030 Patent"); and 6,700,482 ("the '482 Patent") (hereinafter sometimes collectively referred to as "the patents-in-suit"). Copies of the patents-in-suit are attached as Exhibits A-F.

9. DENSO is a supplier of automotive components and systems for all the world's automakers. DENSO makes and sells automobile navigation products, including its E7001 navigation unit (hereinafter sometimes referred to as "DENSO's automobile navigation products"). DENSO has supplied its automobile navigation products to automobile manufacturers throughout the world since at least as early as 1987.

10. DENSO AMERICA is a wholly-owned subsidiary of DENSO and a supplier to automobile manufacturers in the United States. DENSO AMERICA provides sales and engineering services and support to automobile manufacturers in the United States, including General Motors and Toyota, for DENSO's automobile navigation products. DENSO AMERICA has provided sales and engineering services and support for DENSO's automobile navigation products since the 1990's.

11. On June 20, 2006, HONEYWELL sent via facsimile and overnight courier a letter addressed to DENSO accusing DENSO's automobile navigation products of infringing the '286 Patent and the '030 Patent. A copy of the letter is attached as Exhibit G.

12. The letter asserts that HONEYWELL is the owner of the identified patents.

13. The letter further states that HONEYWELL had obtained and tested a Denso automobile navigation product and that HONEYWELL had "determined that this product, which uses GPS/INS and Waypoint Locating technologies, infringes the Honeywell Patents."

14. The letter encourages DENSO to obtain a license not only under the identified patents, but also under additional patents, including the '277 Patent, the '132 Patent, the '945 Patent, and the '482 Patent. The letter states "Denso should also consider licensing the additional Honeywell Patents enumerated in the enclosed patent summary sheet that are relevant to Denso's products. We realize that Denso sells other navigation products, and we would be willing to discuss including such products in any agreement we reach."

15. DENSO's automobile navigation products do not fall within the scope of any valid claim of the patents-in-suit. Consequently, neither DENSO nor DENSO AMERICA is liable to HONEYWELL for patent infringement. A case of actual controversy exists between DENSO and DENSO AMERICA and HONEYWELL, therefore, as a result of HONEYWELL's accusations of patent infringement levied against DENSO. This action is necessary to stop the damage to DENSO and DENSO AMERICA resulting from HONEYWELL's baseless accusations.

COUNT I: DECLARATORY JUDGMENT OF NON-INFRINGEMENT OF THE '286 PATENT

16. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

17. DENSO and DENSO AMERICA are not infringing, nor have they ever infringed, the '286 Patent.

18. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '286 Patent.

COUNT II: DECLARATORY JUDGMENT OF INVALIDITY OF THE '286 PATENT

19. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

20. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '286 Patent for the reason that the '286 Patent is invalid.

COUNT III: DECLARATORY JUDGMENT OF NON-INFRINGEMENT OF THE '277 PATENT

21. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

22. DENSO and DENSO AMERICA are not infringing, nor have they ever infringed, the '277 Patent.

23. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '277 Patent.

COUNT IV: DECLARATORY JUDGMENT OF INVALIDITY OF THE '277 PATENT

24. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

25. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '277 Patent for the reason that the '277 Patent is invalid.

COUNT V: DECLARATORY JUDGMENT OF NON-INFRINGEMENT OF THE '132 PATENT

26. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

27. DENSO and DENSO AMERICA are not infringing, nor have they ever infringed, the '132 Patent.

28. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '132 Patent.

COUNT VI: DECLARATORY JUDGMENT OF INVALIDITY OF THE '132 PATENT

29. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

30. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '132 Patent for the reason that the '132 Patent is invalid.

COUNT VII: DECLARATORY JUDGMENT OF NON-INFRINGEMENT OF THE '945 PATENT

31. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

32. DENSO and DENSO AMERICA are not infringing, nor have they ever infringed, the '945 Patent.

33. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '945 Patent.

COUNT VIII: DECLARATORY JUDGMENT OF INVALIDITY OF THE '945 PATENT

34. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

35. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '945 Patent for the reason that the '945 Patent is invalid.

COUNT IX: DECLARATORY JUDGMENT OF NON-INFRINGEMENT OF THE '030 PATENT

36. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

37. DENSO and DENSO AMERICA are not infringing, nor have they ever infringed, the '030 Patent.

38. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '030 Patent.

COUNT X: DECLARATORY JUDGMENT OF INVALIDITY OF THE '030 PATENT

39. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

40. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '030 Patent for the reason that the '030 Patent is invalid.

COUNT XI: DECLARATORY JUDGMENT OF NON-INFRINGEMENT OF THE '482 PATENT

41. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

42. DENSO and DENSO AMERICA are not infringing, nor have they ever infringed, the '482 Patent.

43. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '482 Patent.

COUNT XII: DECLARATORY JUDGMENT OF INVALIDITY OF THE '482 PATENT

44. DENSO and DENSO AMERICA restate the allegations contained in paragraphs 1-15.

45. Neither DENSO nor DENSO AMERICA is liable to HONEYWELL for infringement of the '482 Patent for the reason that the '482 Patent is invalid.

PRAYER FOR RELIEF

WHEREFORE, DENSO and DENSO AMERICA pray that this Honorable Court:

A. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that DENSO and DENSO AMERICA have not infringed U.S. Patent No. 5,923,286;

B. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that U.S. Patent No. 5,923,286 is invalid;

C. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that DENSO and DENSO AMERICA have not infringed U.S. Patent No. 6,289,277;

D. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that U.S. Patent No. 6,289,277 is invalid;

E. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that DENSO and DENSO AMERICA have not infringed U.S. Patent No. 6,308,132;

F. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that U.S. Patent No. 6,308,132 is invalid;

G. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that DENSO and DENSO AMERICA have not infringed U.S. Patent No. 6,664,945;

H. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that U.S. Patent No. 6,664,945 is invalid;

I. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that DENSO and DENSO AMERICA have not infringed U.S. Patent No. 6,691,030;

J. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that U.S. Patent No. 6,691,030 is invalid;

K. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that DENSO and DENSO AMERICA have not infringed U.S. Patent No. 6,700,482;

L. Enter judgment for DENSO and DENSO AMERICA and against HONEYWELL declaring that U.S. Patent No. 6,700,482 is invalid;

M. Enter judgment declaring that this case is exceptional, and that DENSO and DENSO AMERICA are entitled to recover from HONEYWELL their costs and reasonable attorneys' fees incurred in this action, pursuant to 35 U.S.C. § 285; and

N. Enter judgment granting such other and further relief and damages to DENSO and DENSO AMERICA as justice and equity may require.

Respectfully submitted,

Dated: June 8, 2007

By: ______________________

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Counsel for DENSO CORPORATION and DENSO INTERNATIONAL AMERICA, INC.

Exhibit A

US005923286A

United States Patent [19]

Divakaruni

[11] **Patent Number: 5,923,286**

[45] **Date of Patent: Jul. 13, 1999**

[54] **GPS/IRS GLOBAL POSITION DETERMINATION METHOD AND APPARATUS WITH INTEGRITY LOSS PROVISIONS**

[75] Inventor: **Sudhakar P. Divakaruni**, Scottsdale, Ariz.

[73] Assignee: **Honeywell Inc.**, Minneapolis, Minn.

[21] Appl. No.: **08/735,764**

[22] Filed: **Oct. 23, 1996**

[51] **Int. Cl.**[6] **G01S 5/02**; H04B 7/185

[52] **U.S. Cl.** **342/357**; 701/213

[58] **Field of Search** 342/357, 450, 342/457; 701/213, 214

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,806,940	2/1989	Harral et al.	342/451
5,394,333	2/1995	Kao	364/450
5,461,388	10/1995	Applegate et al.	342/357
5,504,482	4/1996	Schreder	340/995
5,504,492	4/1996	Class et al.	342/357
5,512,903	4/1996	Schmidke	312/357
5,543,804	8/1996	Buchler et al.	342/357
5,583,774	12/1996	Diesel	364/443
5,606,506	2/1997	Kyrtsos	364/449.1
5,657,025	8/1997	Ebner et al.	342/357

FOREIGN PATENT DOCUMENTS

0 629 877	12/1994	European Pat. Off. .
95 34850	12/1995	WIPO .

OTHER PUBLICATIONS

Article entitled Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS), document No. RTCA/DO-208, Jul. 1991, prepared by: SC-159, pp. 19-22.

Appendix F entitled "Least-Squares Residuals RAIM Method" from document No. RTCA/DO-208, Jul. 1991, prepared by SC-159, pp. 1-4.

Article entitled "Implementation of a RAIM Monitor and a GPS Receiver and an Integrated GPS/IRS" by Mats Brenner, in the proceedings of ION GPS-90, Third International Technical Meeting of the Satellite Division of the Institute of Navigation, Sep. 19-21, 1990, located at p. 397.

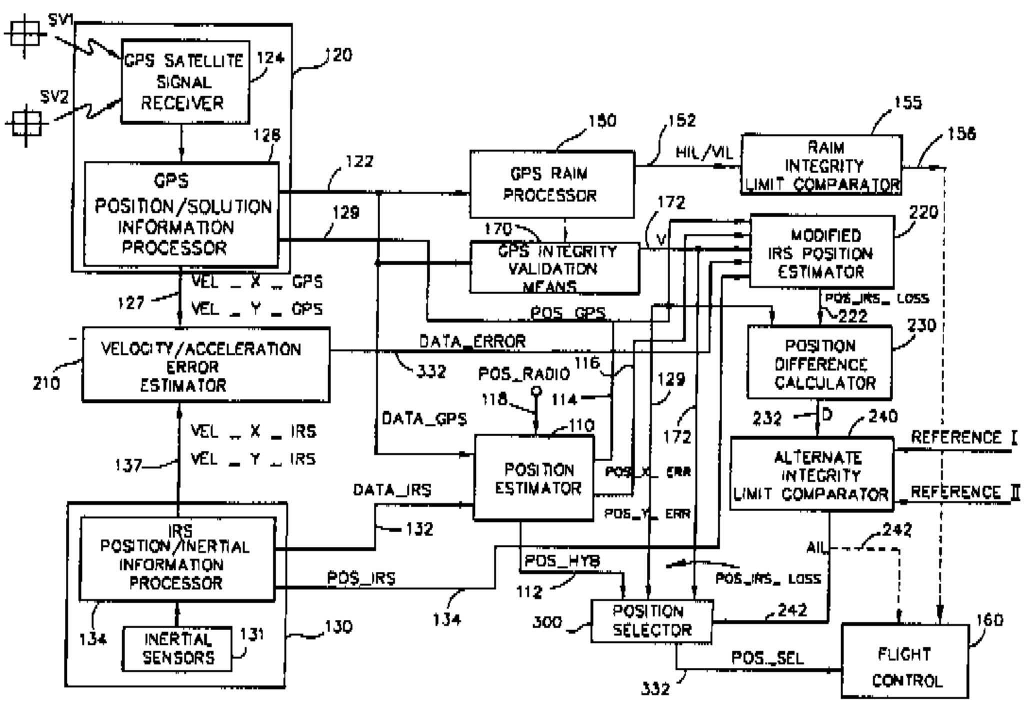
Patent Abstracts of Japan, vol. 013, No. 135 (p-851), Apr. 5, 1989.

Primary Examiner—Thomas Tarcza
Assistant Examiner—Dao L. Pham
Attorney, Agent, or Firm—Charles J. Ungemach; Ronald E. Champion

[57] **ABSTRACT**

A system for use with an inertial reference system and a global position receiver for calculating a position error after a loss of integrity by utilizing the global position system values for position and velocity at a time just before the loss of integrity and by utilizing the inertial reference system position modified by the known error in inertial reference system position as it varies with time and the position error as calculated by the global position system velocity extrapolated over the time since integrity loss.

19 Claims, 3 Drawing Sheets



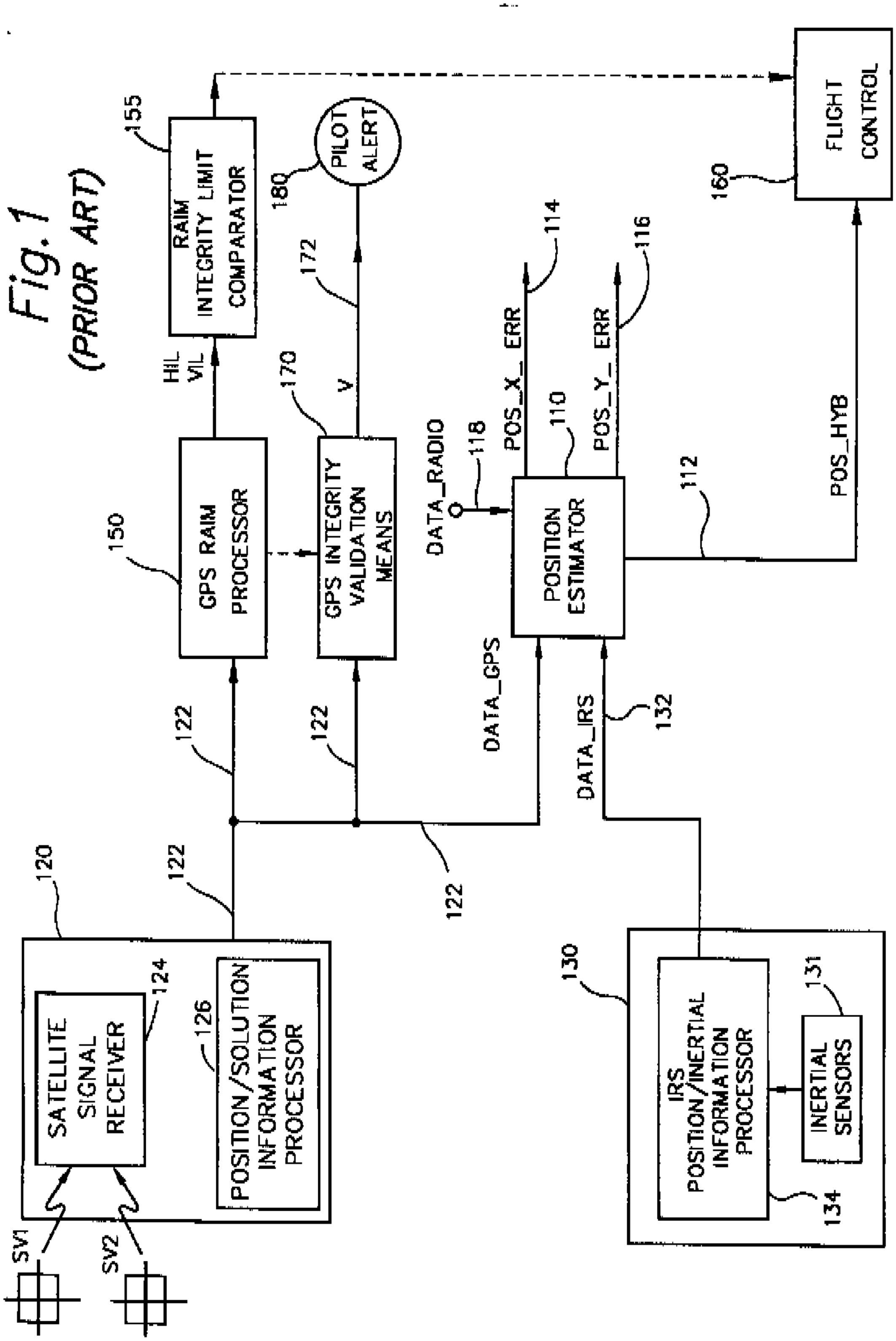


Fig. 1 (PRIOR ART)

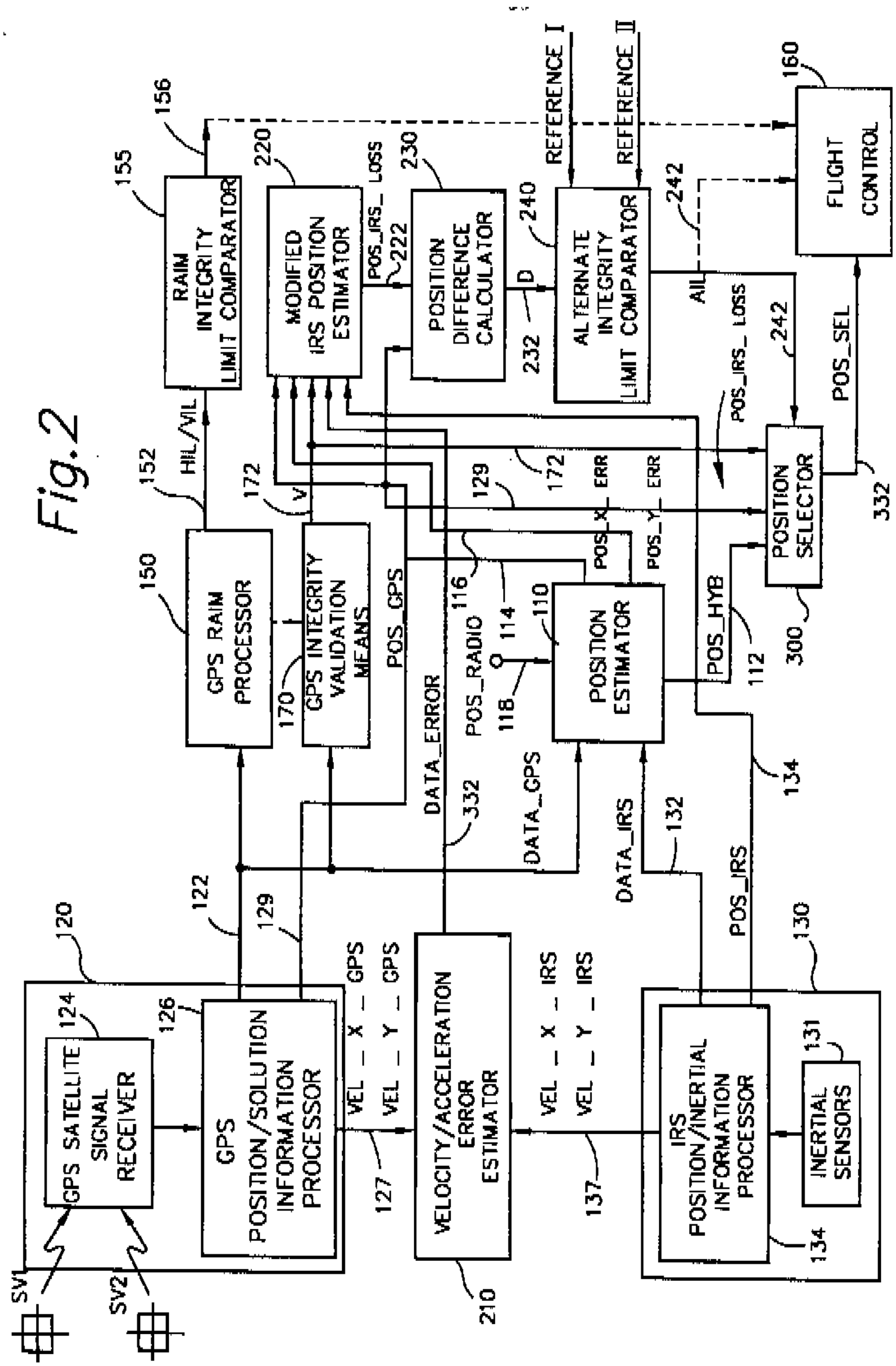
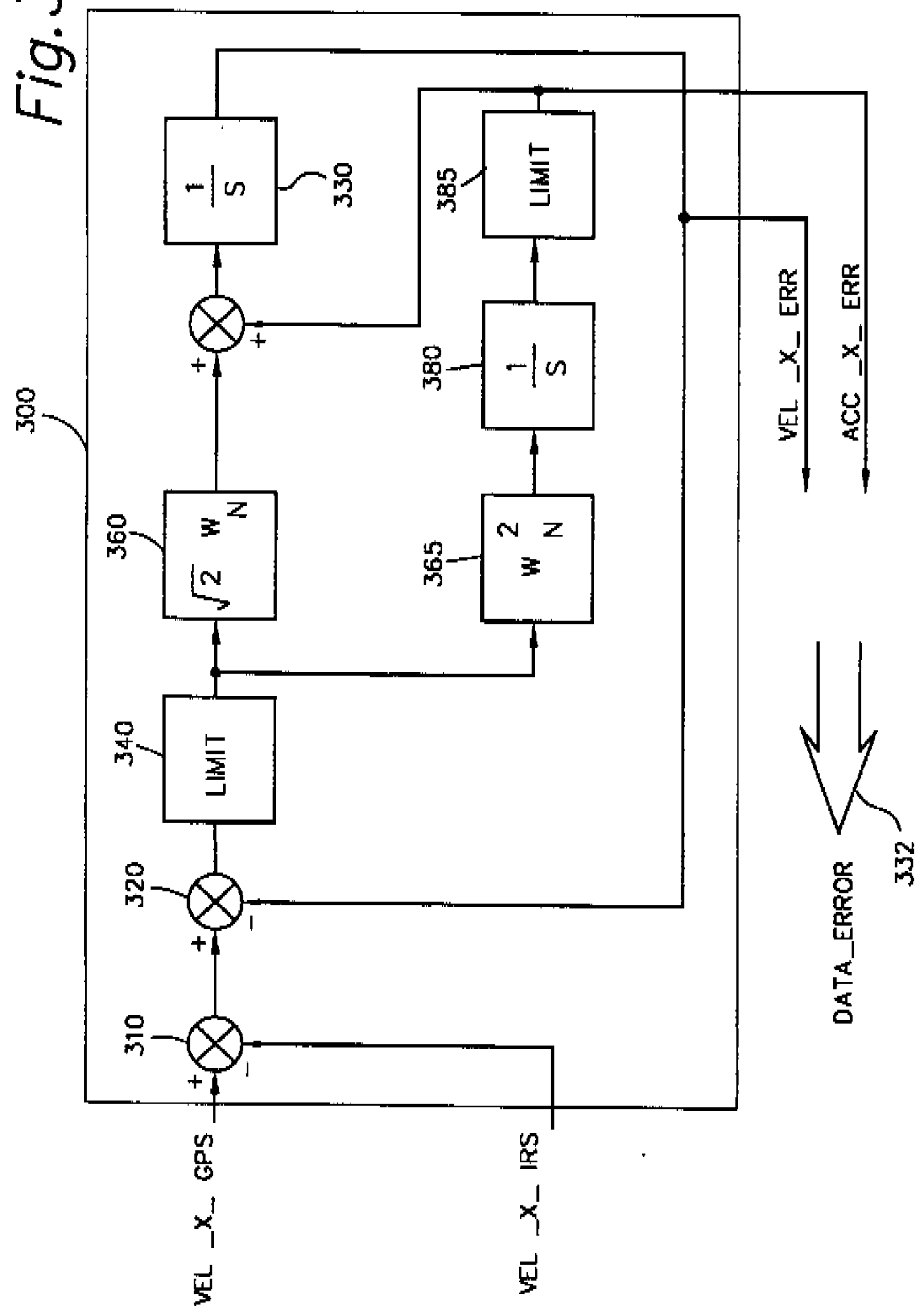

GPS SATELLITE SIGNAL RECEIVER
GPS POSITION/SOLUTION INFORMATION PROCESSOR
VELOCITY/ACCELERATION ERROR ESTIMATOR
IRS POSITION/INERTIAL INFORMATION PROCESSOR
INERTIAL SENSORS
GPS RAIM PROCESSOR
GPS INTEGRITY VALIDATION MEANS
RAIM INTEGRITY LIMIT COMPARATOR
MODIFIED IRS POSITION ESTIMATOR
POSITION DIFFERENCE CALCULATOR
ALTERNATE INTEGRITY LIMIT COMPARATOR
POSITION ESTIMATOR
POSITION SELECTOR
FLIGHT CONTROL
REFERENCE I
REFERENCE II
HIL/VIL
POS_GPS
DATA_ERROR
POS_RADIO
DATA_GPS
DATA_IRS
POS_IRS
POS_HYB
POS_SEL
POS_IRS_LOSS
POS_X_ERR
POS_Y_ERR
AIL
D
VEL_X_GPS
VEL_Y_GPS
VEL_X_IRS
VEL_Y_IRS
SV1
SV2

Fig. 2

Fig. 3


300
310
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LIMIT
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330
1
S
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LIMIT
VEL_X_GPS
VEL_X_IRS
VEL_X_ERR
ACC_X_ERR
DATA_ERROR
332

GPS/IRS GLOBAL POSITION DETERMINATION METHOD AND APPARATUS WITH INTEGRITY LOSS PROVISIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to a system employed for determining the global position of a mobile unit by employment of both an inertial reference system (IRS) and a satellite positioning system (GPS), and more specifically, a system which employs a provision for determining the mobile unit's global position and corresponding integrity during those periods of time in which the GPS satellite constellation is insufficient for establishing GPS integrity limit values by employment of RAIM.

2. Description of the Related Art

Satellite positioning systems are now well-known in the art. Such systems, for example, NAVSTAR-GPS, are rapidly being employed for a determination of the geocentric position of mobile units, such as water and land vehicles, space and aircraft, and survey equipment, to name a few.

In aircraft, GPS systems are being utilized for navigation, flight control, and airspace control. These GPS systems may operate independently or in combination with inertial reference systems or attitude heading reference systems in order to provide information particularly during a flight mission.

Global positioning systems, hereinafter referred to as "GPS", similar to NAVSTAR, commonly use a GPS receiver, located on a mobile unit, for receiving satellite information signals transmitted from a plurality of satellites. Each GPS satellite transmits a satellite information signal containing data that allows a user to determine the range or distance between selected GPS satellites and the antenna associated with the mobile unit's GPS receiver. These distances are then used to compute the geocentric position coordinates of the receiver unit using known triangulation techniques. The computed geocentric position coordinates may, in turn, be translated to earth latitude and longitude coordinates.

In order to determine the position of the GPS receiver, a minimum of four unique satellite information signals are required, rather than the expected three (three position, unknown coordinates). This is so, since the GPS receiver generally includes a receiver clock which is not as accurate as the atomic clock normally associated with each of the satellites. Therefore, receiving satellite information signals from four different satellites provides a complete solution which permits the correction of any receiver clock error as is well-understood in the art. Herein, the GPS receiver position derived by the triangulation technique using data from multiple satellites is referred to as the "GPS estimated position", identified as POS_GPS. The accuracy of this estimated GPS position is dependent upon many factors, including, among others, atmospheric conditions, selective satellite availability, and the relevant position of the satellites with respect to the line of sight view of the satellites.

Associated with a GPS estimated position is a "position error bound" as particularly defined by accepted GPS systems standards which have been developed by the Radio Technical Commission for Aeronautics (RTCA), in association with aeronautical organizations of the United States from both government and industry. The RTCA has defined the phrase "GPS system integrity" as the ability of a GPS system to provide timely warnings to users when the GPS system should not be used for navigation. "System integrity" is particularly identified in a document entitled "Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)", document number RTCA/DO-208, July 1991, prepared by: SC-159, beginning at section 1.5. As described therein, GPS is complicated in that it is a four-dimensional system involving three components of position and one time component. As also described in the aforesaid RTCA publication, the signal-in-space error transforms into a horizontal position error via a relatively complex function of a satellite constellation geometry at any given moment. The GPS integrity system must interpret the information it has about the received GPS signals and error terms in terms of the induced horizontal position error, commonly referred to as the "position error bound", and then make a decision as to whether the position error bound is outside the allowable radial error, specified for a particular phase of the flight mission in progress. The allowable error is referred to as the "alarm limit", herein referred to as the "integrity alarm limit". If the horizontal position error bound is found to exceed the integrity alarm limit, a timely warning must be issued by the GPS receiver or subsystem to notify the pilot that the GPS estimated position should not be relied upon.

Two rather distinct methods of assuring GPS integrity have evolved as civilian use of GPS has progressed. One is the Receiver Autonomous Integrity Monitoring (RAIM) concept, and the other is the ground monitoring approach that goes under the "GPS Integrity Channel" (GIC). The intent of both of these methods is the calculation of the position error bound with regard to the current GPS estimated position so that it may be compared with the alarm limit associated with a particular phase of a flight mission.

The receiver autonomous integrity monitoring system (RAIM) employs a self-consistency check among the measurements, more specifically, GPS pseudo range measurements. Satellite redundancy is required to perform a self-consistency check on an instantaneous basis. Thus, five satellites must be in view, i.e., five satellite information signals received and pseudo range measurements calculated by a GPS receiver. If fewer than five satellites are in view, the value of the predicted position error bound will be infinite. Also, constraints are placed on the satellite constellation geometry that must be met if the self-consistency check is to be effective in the presence of noise, e.g., azimuth angle of the satellite relative to user position. Generally, a satellite constellation with many satellites in view permits a robust integrity monitoring system. Conversely, a satellite constellation having only a few satellites in view, may limit the availability of an integrity monitoring system. Thus, there may be short periods when a good consistency check is not possible (less than five satellites in view). The main feature of RAIM is that it is completely self-contained and relatively easy to implement in software.

Examples of RAIM may be found in the aforementioned RTCA publication, Appendix F, and also in an article entitled "Implementation of a RAIM Monitor and a GPS Receiver and an Integrated GPS/IRS" by Mats Brenner, located at page 397, in the proceedings of ION GPS-90, Third International Technical Meeting of the Satellite Division of the Institute of Navigation, Sep. 19–21, 1990.

GPS systems which incorporate RAIM output a position error bound value which represents the probabilistic radial errors of the navigation solution, namely, the GPS estimated position of the receiver unit. Currently, RAIM may generate several numbers, including, a horizontal position error bound value (sometimes referred to as HIL—Horizontal

Integrity Limit), a vertical position error bound value (sometimes referred to as VIL—Vertical Integrity Limit), and spherical position error bound for the current time, i.e., the instance of time that GPS measurements occurred.

Once calculated, the position error bound value(s), HIL and/or VIL, may be compared with selectable integrity alarm limit values to determine if the pilot can rely on the derived GPS estimated position for the current phase of the light mission. It should be recognized that some interpretation may be required dependent upon the GPS receiver's ability to simultaneously receive a plurality of satellite information signals as is well-understood in the art. However, advancements in the art of 12-channel GPS receivers have made it no longer necessary to rely on interpolation of data as before.

The allowable integrity alarm limit values may change depending upon the phase of the flight mission. For instance, if a pilot is flying in the terminal phase, the integrity alarm limit may be less stringent than if the pilot is in the approach phase of the flight mission. If the pilot is to transition from the terminal phase to the approach phase, the pilot needs to know whether the current position error bound is sufficient to allow the pilot to rely upon the GPS solution to make the transition.

As is well understood in the art, inertial reference systems employ a plurality of inertial sensors, for example, gyroscopes and accelerometers, for determining an IRS estimated position of the aircraft, hereinafter referred to as "POS_IRS". Generally, the IRS estimated position is in terms of latitude and longitude (altitude being separately determined by other means such as an altimeter of some type). However, inherent in such inertial sensors are particular bias and drift terms which affect the accuracy of the IRS estimated position of the aircraft utilizing solely an inertial reference system. Since high inertial grade sensors, i.e., low bias and drift characteristics, are very costly, it is desirable to minimize the cost of the IRS system by using lower grade inertial sensors.

In the art, a compromise has been reached by using lower grade inertial reference systems in combination with a global positioning system to produce a high quality--lower cost navigation and flight control system. This is sometimes referred to as a Hybrid INS/GPS or IRS/GPS Inertial Reference System. These systems achieve excellent results since low grade inertial reference systems produce very accurate dynamic response characteristics, whereas, GPS provides very accurate static position information, but less accurate dynamic response information. Combining both the IRS estimated position and inertial reference information with GPS estimated position information provides excellent user position information for flight navigation and flight control applications. Accordingly, a flight management system (FMS), combines the excellent features of both the IRS and the GPS systems to provide position and inertial reference information which permits excellent flight management, flight control and navigation.

An example of a hybrid IRS/GPS system is Honeywell Inc.'s "Global Positioning Inertial Reference Unit (GPIRU) identified as an HG 1050 AG01 which is referred to as a "hybrid" system since it provides position and inertial information which are a resultant combination of GPS and inertial reference system information. The GPIRU includes an inertial reference unit with gyros and accelerometers to provide information about aircraft attitude and rate of change of position as well as providing a first source of position information. The GPIRU also receives inputs from a Global Position System Receiver to provide a second and independent source of information about the aircraft position. The two sets of information are mathematically combined in a Flight Management System (FMS) to determine a hybrid position POS_HYB. In turn, this position value along with attitude and rate signals from the Inertial Reference Unit may be provided in a flight control for controlling aircraft.

A problem, however, with flight management systems employing GPS and IRS is the questionable integrity of the GPS estimated position information during those times in which RAIM integrity limit values are no longer available, i.e. insufficient satellite information to provide useful integrity position error bound values.

BRIEF DESCRIPTION OF THE INVENTION

The present invention uses the FMS to calculate a poisition error at anytime, t, after the loss of integrity at time, T_L, by utilizing the GPS values for position and velocity at time T_L just before loss of integrity and by utilizing the IRS position modified by the known error in IRS position as it varies with time and the position error as calculated by the GPS velocity extrapolated over the time $(t-T_L)$.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a combined inertial reference system and a satellite positioning system known in the prior art.

FIG. 2 is a combined inertial reference system and satellite positioning system in accordance with the present invention.

FIG. 3 is a block diagram illustrating a second order filter.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Illustrated in FIG. 1 is a simplified block diagram of a mobile unit, a hybrid IRS/GPS estimator commonly employed on aircraft. A position estimator 110, for example, as part of a flight management system as described earlier, receives as inputs (i) GPS output information identified as DATA_GPS, further identified by numeral 122, from a satellite positioning system receiver 120, and (ii) an inertial reference output information indicated by DATA_IRS, further identified by numeral 132 from inertial reference system 130. Position estimator 110 processes DATA_IRS and DATA_GPS to derive (i) a hybrid position estimate identified as POS_HYB, and position error estimates identified as POS_X_ERR and POS_Y_ERR. This information, which will be described in detail below, is provided on output signal lines 112, 114, and 116 respectively.

As is well-understood in the art, satellite positioning system receiver 120 includes a satellite signal receiver portion 124 for receiving satellite information signals from a plurality of satellite vehicles, for example, SV1 and SV2, which form, in part, a constellation of satellite vehicles. One example, already indicated, is the NAVSTAR GPS constellation of satellites. In turn, the satellite information signals are operated on by GPS position/solution information processor 126 for providing a GPS solution information identified as DATA_GPS on signal line 122. This information is provided as an input to position estimator 110, to a GPS integrity validation means 170 and to a GPS RAIM processor 150 on common signal line 122.

Inertial reference system 130 includes a plurality of inertial sensors indicated by block 131 as inputs to an IRS position/inertial information processor 134 for providing

IRS derived position and inertial information on signal line 132, designated DATA_IRS. This information is provided as an input to position estimator 110.

Position estimator 110, which forms in part a flight management system known in the art, utilizes the GPS solution information, DATA_GPS, as a continuous reference for enhancing the accuracy of the IRS position/inertial information DATA_IRS, particularly for minimizing resultant bias terms which are inherent in the inertial sensors 131. Position estimator 110 may also include an input for receiving radio position information indicated by numeral 118, e.g. VOR signal information designated as DATA_RADIO.

Position estimator 110 provides as an output on signal line 112 an estimated position identified as POS_HYB. The output POS_HYB of position estimator 110 is provided as an input to flight control block 160, useful for deriving aircraft flight control signals to achieve a desired aircraft position. For example, flight control 160 may be employed for en-route navigation, terminal approach, and landing of an aircraft.

Before proceeding, it should be noted, as commonly understood in the art, that position estimator 110 employs filtering techniques, such as second order filters or Kalman filters for deriving the aforesaid output information. The position error estimates POS_X_ERR and POS_Y_ERR represent the latitude and longitude errors which are related to the differences between the GPS derived position identified as POS_GPS and the inertial reference system derived position identified as POS_IRS associated with DATA_GPS and DATA_IRS, respectively.

Further, it should be noted that associated with outputs DATA_GPS, DATA_IRS, POS_HYB, POS_X_ERR, and POS_Y_ERR are discrete time values. Accordingly, system timing (not shown) and/or interpolation or extrapolation functions are, of course required, so that position estimator 110 combines the GPS and IRS information for substantially the same time values. In the following exposition, synchronization of time values should be assumed and that each value has a discrete time associated therewith.

As is well-understood in the art, the GPS position solution information must be validated by a GPS system integrity monitor. GPS RAIM processor 150 is intended to operate on the GPS solution information DATA_GPS for determining at least horizontal integrity limit values HIL, and may also provide vertical integrity limit values VIL. In turn, these integrity limit values are compared in RAIM Integrity Limit Comparator 155 with selected integrity alarm limit values dependent upon the phase of the flight mission. In turn, if HIL/VIL is acceptable, the pilot will allow control of the aircraft based upon the outputs of position estimator 110. On the other hand, if HIL/VIL exceeds the integrity alarm limit values, the pilot must be alerted so that corrective action may be taken.

A second scenario is, of course, the case where RAIM is unavailable, i.e., insufficient number of tracked satellites. In this scenario, the constellation of satellites as observed by the GPS receiver 120 may be such that it is impossible for GPS RAIM processor 150 to arrive at a solution for obtaining HIL and/or VIL integrity limit values—these being resultant large values for HIL/VIL. Accordingly, GPS integrity validation means 170 is employed to provide an indication as to whether or not there exists RAIM integrity monitoring availability, i.e., sufficient satellite information signals to be able to calculate the integrity limit values, HIL and/or VIL. As illustrated in FIG. 1, GPS integrity validation means 170 receives as its input the GPS receiver output on signal line 122 for making such determination, i.e. RAIM integrity monitoring available or not available, and providing such indication as signal "V" on signal line 172.

As is well understood in the art, GPS integrity validation means 170 represents a simple analysis of the number of satellite information signals tracked by the GPS signal receiver 120 which meet predetermined criteria, e.g., elevation angle. As described earlier, RAIM availability is conditioned upon having at least five satellites tracked for receiving satellite information therefrom. Secondly, GPS RAIM processor 150 is generally operable not to utilize satellite information from those satellites which are less than a selected elevation angle. In this situation, even though a proper number of satellites have been tracked, the information may not be reliable due to the elevation angle of the satellite relative to the user's position. In either case, the function of GPS integrity validation means 170 is to provide an indication of the "non-availability" of RAIM integrity limit values, and is provided as an input to a pilot alert mechanisms indicated by block 180.

It should be noted that blocks 150, 155, and 170 are shown as discrete functional blocks, for explanation purposes. However, it should be understood that they may be incorporated together, and may also be part of the GPS receiver, itself, as should be appreciated by those skilled in the art.

Reliance upon the system as described in FIG. 1 by a pilot is extremely dependent upon RAIM availability. In other words, the user position estimate POS_HYB is only useful during those times in which RAIM integrity limit values are available. Loss of RAIM will have adverse consequences, for example, requiring the pilot to abort a terminal approach or landing.

For example, consider the situation in which RAIM is available and an aircraft has already begun the terminal phase of the flight mission prior to landing. Assume now that during this phase of the flight mission that the constellation of satellites changes to a condition in which RAIM integrity monitoring is no longer available. In this scenario, the pilot is alerted via a warning display mechanization 180 or inputs to the flight control system 160 such as to cause the pilot to disengage the flight control system which responds primarily to the aircraft position POS_HYB since GPS data may no longer be reliable. In this scenario, depending upon the weather conditions, namely, cloud cover and the like, the pilot must determine whether to manually fly the aircraft, or abort the phase of the flight mission in which RAIM integrity monitoring was lost, i.e., not available. In the latter case, the pilot may take appropriate actions to require some delay time at which the constellation of satellites would be in proper position to provide RAIM integrity monitoring availability.

It should be noted, one technique for avoiding the above scenario, is predictive RAIM. Predictive RAIM attempts to known in advance that RAIM integrity monitoring is available before entering a particular phase of the flight and would be available throughout the entirety of the phase of the flight mission. This is particularly important in the approach and landing phases of the flight mission. If predictive RAIM indicates "non-availability", the pilot may take certain actions, e.g., decrease the aircraft velocity such that landing takes place at a later time when RAIM is once again available.

Illustrated in FIG. 2 is one embodiment of the present invention for providing an alternate GPS integrity limit process during those time periods in which the usual RAIM integrity monitoring is not available. In FIG. 2, similar functioning blocks as those illustrated in FIG. 1 have retained the same numeral designation, and therefore will not be further described. FIG. 2, in addition to those components as shown in FIG. 1, further includes velocity/acceleration error estimator **210**, modified IRS position estimator **220**, position difference calculator **230**, alternate integrity limit comparator **240**, and position selector **300**.

Before proceeding, it should be understood that GPS position/inertial information processors may provide position/inertial information in a variety of coordinate reference frames. Commonly, GPS information provides position information in an earth-centered, earth-fixed, coordinate reference frame. In turn, this information may be translated into latitude and longitude values. The inertial GPS solution information may include velocity information in terms of north direction and east direction, as is commonly found in the art. These values, of course, are mere translations and/or transformations of the earth-centered, earth-fixed, position information. Accordingly, as depicted in FIG. 2 and the explanation which follows, north and east directions are represented by X and Y, respectively, which also relates to latitude and longitude, respectively. Further, in the following exposition, the term "POS" represents position, and the term "VEL" represents velocity.

Referring again to FIG. 2, velocity/acceleration error estimator **210** receives as inputs (i) GPS derived velocity information in the X and Y direction, and (ii) IRS velocity information in the X and Y direction derived from the inertial sensors, are provided as inputs. These terms may be represented by:

VEL_X_GPS	GPS derived velocity, X direction
VEL_Y_GPS	GPS derived velocity, Y direction
VEL_X_IRS	IRS derived velocity, X direction
VEL_Y_GPS	IRS derived velocity, Y direction

where the IRS and GPS designate refers to data derived from the inertial reference system **130** and the GPS receiver **120** respectively. As before, these terms have substantially identical corresponding real time values associated therewith.

Velocity/acceleration error estimator **210** provides as an output information designated as "DATA_ERROR" which represents discrete acceleration and velocity error, or bias terms in the IRS position/inertial information. Such terms may be represented by VEL_X_ERR, VEL_Y_ERR, ACC_X_ERR, and ACC_Y_ERR, X and Y velocity and acceleration errors, respectively. Modified IRS position estimator **220** receives as inputs DATA_ERROR, the inertial reference system **130** position information represented by POS_IRS, the position errors POS_X_ERR and POS_Y_ERR, and validation signal on signal lines **332**, **134**, **114**, **116**, and **172**, respectively.

Modified IRS position estimator **220** is intended to provide an output on signal line **222** representative of a modified IRS position estimate designated as POS_IRS_LOSS which represents an estimate of the real position of the user during the time period in which GPS RAIM integrity monitoring was not available (i.e., RAIM "LOSS") following a time period when RAIM integrity monitoring was available. Modified IRS position estimator **220** is intended to operate on the aforesaid input information for determining a position estimate which may be mathematically described as follows:

$$POS\_IRS\_LOSS(t) = [POS\_IRS(t)] -$$

$$[POS\_ERR[t_0] + [VEL\_ERR(t_0)][t - T_L] + [.5][ACC\_ERR(t_0))][t - t_L]^2$$

These terms, of course, having their coordinate components, i.e. X and Y. The above expression is simply a statement that the modified IRS estimated position POS_IRS_LOSS at time "t" is the measured IRS position POS_IRS(t) corrected by the velocity and acceleration error terms provided by Velocity/Acceleration error estimator **300** and the position error estimates provided as an output of position estimator **110**—the latter being provided by a filtered error estimator described earlier.

In component terms, then

$$D = R_E * \sqrt{(P_1^x - P_2^x)^2 + (P_1^y - P_2^y)^2 * COS(LATV)}$$

x, y = latitude, longitude, position coordinates

where
P_1^x = POS_X_GPS
P_1^y = POS_Y_GPS
P_2^x = POS_Y_IRS
P_2^y = POS_Y_IRS
$LATV$ = $\frac{P_1^x + P_2^x}{2}$
RE = Earth Radius at $LATAV$

Again referring to FIG. 2, the modified IRS position estimate identified as POS_IRS_LOSS provided on output signal line **222** is presented to position difference calculator **230**. Position difference calculator **230** receives as a second input the GPS derived position identified as POS_GPS provided on output signal line **129** from GPS receiver **120**. Position difference calculator **230** is intended to derive the difference in position D between the GPS derived position and the modified IRS position estimate, as mathematically described by:

$$D = R_E * \sqrt{(P_1^x - P_2^x)^2 + (P_1^y - P_2^y)^2 * COS(LATV)}$$

x, y = latitude, longitude, position coordinates

where
P_1^x = POS_X_GPS
P_1^y = POS_Y_GPS
P_2^x = POS_Y_IRS
P_2^y = POS_Y_IRS
$LATV$ = $\frac{P_1^x + P_2^x}{2}$
RE = Earth Radius at $LATAV$

It should be noted that the position difference "D" represents the magnitude of a vector between (a) the position coordinates derived from the GPS solution provided by GPS receiver **120**, and (b) the position coordinates derived by the IRS position/inertial information processor **134** as modified by the velocity/acceleration errors DATA_ERROR provided as an output of modified IRS position estimator **220**, namely POS_IRS_LOSS. The value "D" represents an "alternate integrity limit" value since it relates to the errors in the IRS system **130** at the time RAIM integrity monitoring was lost. The value D is provided as an output on signal line

232, and presented as an input to alternate integrity limit comparator 240.

Alternate integrity limit comparator 240 receives as inputs the alternate integrity limit value D, and integrity alarm limit reference values identified as reference-I and reference-II, dependent upon the phase of the flight mission. Alternate integrity limit comparator 240 is intended to compare the deviation between the alternate integrity value D and a predetermined flight phase integrity alarm limit value (i.e., the alarm limit reference values). The aforesaid integrity alarm limit value is of course dependent upon the phase of the flight mission (for example, terminal phase, approach phase, or final approach (landing) phase). Alternate integrity limit comparator 240 provides an indication of the alternate integrity comparison designated AIL on signal line 242. In turn, output signal line 242 is presented as an input to position selector 300, and flight control 160.

Position selector 300 receives as inputs, the position estimator 110 derived position POS_HYB on signal line 112, and the GPS derived position POS_GPS from GPS receiver 120 on output signal line 129. Further, position selector 300 receives as an input, the output V provided by GPS integrity validation means 170, and the output AIL from alternate integrity limit comparator 240 on signal lines 172 and 242. Position selector 300 provides as an output on signal line 332 an estimated position identified as POS_SEL dependent upon the output of GPS integrity validation means 170, the alternate integrity limit comparator 240, and the position inputs as aforesaid. This signal is presented to flight control 160.

Operation of the embodiment of the invention depicted in FIG. 2 will now be described.

RAIM Available

Consider the situation in which an aircraft is in the terminal phase of the flight mission, and the constellation of GPS satellites is such the GPS receiver 120 is able to track five or more satellites which have an elevation angles greater than some selected minimum. In these circumstances, GPS RAIM processor 150 receiving the GPS position/solution information, is able to calculate the horizontal integrity limit value HIL. Secondly, GPS integrity validation means 170 outputs V indicating that RAIM is available.

At the same time, position estimator 110 derives an estimated aircraft position POS_HYB as a function of the GPS data, identified as DATA_GPS and the IRS data, identified as DATA_IRS to calculate the estimated position POS HYB by a matter well-known in the art as already described with reference to FIG. 1. Upon receiving a RAIM available signal indication on signal line 172, position selector 300 sets the output 332 such that POS_SEL=POS_HYB. This estimated position, POS_SEL, is provided as an output to flight control 160. In turn, flight control 160 will utilize the estimated aircraft position POS_SEL if, and only if, the integrity limit value HIL is below a preselected value. Accordingly, flight control 160 includes pilot alarms, navigation, and flight control processing functions as well-known in the art.

RAIM Changes to Non-Availability

Now consider the situation when the GPS constellation is such that RAIM integrity monitoring is no longer available at time T_L. In these circumstances, modified IRS position estimator 220 (i) acknowledges the fact that RAIM is no longer available, (ii) stores the value of T_L, (iii) stores the velocity/acceleration error estimates presented by DATA_ERROR corresponding to time T_L, and (iv) calculates the modified IRS position POS_IRS_LOSS for time after T_L and until RAIM becomes available again.

In these circumstances, position selector 300 sets POS_SEL=POS_IRS_LOSS. Concurrently, the difference D between the modified IRS position estimate POS_IRS_LOSS differential and the GPS position solution GPS_POS is calculated by position difference calculator 230. Alternate integrity limit comparator 240 compares the output value D with the flight phase alarm limit reference values corresponding to the particular phase of flight. If D is greater than the acceptable limit value reference, the output AIL of alternate integrity limit comparator 240 provides a go/no go indication, AIL, as an input to flight control 160. In these circumstances, the estimated position indicated by POS_SEL should not be used for flight control, and that the pilot needs to take corrective action as being appropriate.

RAIM Returns to Available

Upon the GPS satellite constellation changing to a condition at which RAIM is now available, position selector 300 will set its output POS_SEL to POS_HYB as before.

FIG. 3 illustrates one embodiment of a velocity/acceleration error estimator 210 in the form of a second order filter. The nomenclature shown in FIG. 3 is for the "X" direction, and a similar implementation is required for the "Y" direction. Thereshown is block 310 for forming the difference calculations between the GPS derived velocity value and the IRS derived velocity value for the X direction as identified by: VEL_X_GPS, and VEL_X_IRS, respectively.

In turn, block 320 forms the difference between the output of block 310 and the velocity error term VEL_X_ERR. The filter further includes integrator 330 and integrator 380, value limiters 340 and 385, and gain blocks 360 and 365.

As illustrated, the acceleration error term "ACC_X_ERR" is equal to the output of limiter block 340 multiplied by gain block 365, integrated by integrator 380, and subsequently being passed through limit block 385. The velocity error term VEL_X_ERR being substantially equal to the output of limit block 340 passing through gain block 360 and summed with the acceleration error term ACC_X_ERR before being integrated by block 330, forming the velocity error term.

The foregoing description of the present invention has been described in terms of simplified schematic block diagrams where each one of the blocks generally employs complex systems employing specific software for executing complex mathematical functions for deriving the intended information. It should be recognized that these schematic block diagrams particularly illustrated in the Figures may be configured by employment of many electronic subsystems, computers and software/firmware implementations. The signal lines, shown in singular form, may represent one or more data buses for providing the intended information as should be appreciated by those skilled in the art. Further, as is well-understood in the art, a single electronic/software subsystem may be employed for performing the appropriate calculations for the generation of all of the described data, except for the details of the GPS signal receiver for receiving the GPS satellite information signals, as well as the inertial sensors themselves. All of these variations as just described are intended to be within the true spirit and scope of the present invention.

Although the present invention has particular applicability to flight control for aircraft or spacecraft, and the like, it is intended to be within the true spirit and scope of the present invention for applications beyond that of flight control.

Lastly, although the velocity and acceleration error estimator has been illustrated by employment of a simple second order filter, other filters are within the scope of the present invention, for example a six or nine state Kalman filter to include the funciton of block **130**.

By way of the Figures illustrated herein, a technique has been disclosed for estimating the velocity and acceleration errors of an inertial reference system by processing GPS derived velocity information and IRS derived velocity information in a second order filter for a subsequent determination of an IRS derived user position modified by the aforesaid velocity and acceleration errors. The error estimates are frozen at a time when the GPS satellite information signals are sufficient to provide a RAIM integrity. However, when the RAIM integrity information is not available, but the GPS position solution had been deemed to have adequate accuracy prior to loss of RAIM availability, a real time IRS user position is modified with these estimated velocity and acceleration errors to provide a highly reliable user position in the absence of RAIM integrity. In turn, an alternate integrity limit value is established, that value being the magnitude of difference between the current GPS position POS_GPS and the modified IRS position estimate, POS_IRS_LOSS.

The IRS position POS_IRS modified by the velocity and acceleration error estimates IRS_POS_LOSS is based on an assumed inertial reference system error model. This model reflects accurately the fact, that in the short term, the inertial reference system performance is governed by the velocity errors. In the absence of any calibration of these errors, the logical practice is to assume their specification limits. For this reason, the 99.9 percentile value assumed for the position error growth rate can be as high as 12 nautical miles per hour. This value, when used in IRS based alternate integrity computations, reaches an alarm limit of 0.3 nautical miles (typical for approach phase of the mission) in 1.5 minutes. But, in accordance with the present invention, the estimated velocity errors correct the IRS velocities, thereby reducing the value of any residual errors. Further, the accuracy of the alternate user position, POS_IRS_LOSS made using both velocity and acceleration error estimates, is considerably enhanced. It is believed that the residual errors in the computations are at most of the order of 3 nautical miles per hour on a 99.9 percentile basis. At this rate, alarm limits of 0.3 nautical miles will be reached in six minutes, a four-fold improvement over current implementations.

The embodiments of an invention in which an exclusive property or right is claimed are defined as follows:

1. A combined inertial reference system and a satellite positioning system for determining user position comprising:

an inertial reference system employing inertial sensors for providing IRS position and inertial reference information, including IRS velocity information, derived from output information from said inertial sensors;

a satellite positioning system receiver for providing a GPS position solution including a resultant GPS position and resultant GPS velocity information derived form satellite information from signals transmitted from a plurality of satellites;

validation means responsive to at least the number of said plurality of satellites transmitting said satellite information signals for indicating a non-availability time period when said number is below that which is required to provide at least one integrity limit value associated with the accuracy of said GPS solution, as opposed to an integrity time period when said number is sufficient to provide said at least one integrity limit value;

error estimator means for determining velocity and acceleration error estimates associated with said IRS inertial information as a function of said IRS velocity information and said resultant GPS velocity information;

coast position estimator means for determining a first estimated position of the user's position during said non-availability time period as function of said velocity and acceleration error estimates occurring at the beginning of said non-availability time period, the elapsed time accumulated since the beginning of said non-availability time period, and the IRS position.

2. The combined inertial reference system and a satellite positioning system of claim **1** further comprising:

IRS/GPS position solution determining means for determining a second estimated position of the user's position as a function of a t least said IRS position and inertial information and said resultant GPS position and resultant GPS velocity information;

position selector means for providing as an output thereof said second estimated position for time during an integrity time period, and said first estimated position for time during a non-availability time period.

3. The combined inertial reference system and a satellite positioning system of claim **1** wherein said error estimator means provides a second order filter having as it input the difference between corresponding components of said resultant GPS velocity and said IRS velocity.

4. The combined inertial reference system and a satellite positioning system of claim **3** wherein said error estimator means includes (i) a second order filter having as its input the difference between north direction components of said resultant GPS velocity and said IRS velocity, and as outputs corresponding north direction velocity and acceleration bias values, and (ii) a second order filter having as it input the difference between east direction components of said resultant GPS velocity and said IRS velocity, and as outputs the corresponding east direction velocity and acceleration bias values.

5. An apparatus for determining the position of a vehicle, the apparatus comprising:

a global positioning system (GPS) communicating with a plurality of satellites and providing a GPS position signal;

an inertial reference system (IRS) providing an IRS position signal;

a position estimator providing a hybrid position signal based upon th eGPS position signal and the IRS position signal;

an IRS position estimator providing an estimated IRS position signal based upon the IRS position signal, the velocity of the vehicle, and the acceleration of the vehicle; and

a position selector providing a vehicle position signal, wherein the vehicle position signal corresponds to the hybrid position signal when the GPS position signal is reliable, and wherein the vehicle position signal corresponds to the estimated IRS position signal when the GPS position signal is unreliable.

6. The apparatus of claim **5** wherein the GPS position signal is unreliable when receiver autonomous integrity module (RAIM) information is unavailable from the global positioning system.

7. The apparatus of claim 5 wherein the GPS position signal is unreliable when the global positioning system communicates with fewer than five satellites.

8. The apparatus of claim 5 further comprising a RAIM availability module that receives the GPS position signal and provides a RAIM availability signal to the position selector.

9. The apparatus of claim 5 further comprising a RAIM availability module that receives the GPS position signal and provides a RAIM availability signal to the IRS position estimator.

10. The apparatus of claim 5 further comprising a velocity/acceleration error estimator that receives a GPS velocity based upon the velocity of the vehicle from the global positioning system and provides a data error signal to the IRS position estimator.

11. The apparatus of claim 5 further comprising a velocity/acceleration error estimator that receives an IRS velocity based upon the velocity of the vehicle from the inertial reference system and provides a data error signal to the IRS position estimator.

12. The apparatus of claim 10 further comprising a velocity/acceleration error estimator that receives an IRS velocity based upon the velocity of the vehicle from the inertial reference system.

13. The apparatus of claim 11 wherein the velocity/acceleration error estimator comprises a second order filter.

14. The apparatus of claim 12 wherein the velocity/acceleration error estimator comprises a second order filter.

15. A method of determining the position of a vehicle having a velocity and an acceleration, the method comprising the steps of:

providing a GPS position signal from a global positioning system;

providing an IRS position signal from an inertial navigation system;

determining if the GPS position signal is reliable;

providing a hybrid position signal to a flight control when the GPS position signal is reliable, the hybrid position signal being based upon the GPS position signal and the IRS position signal; and

providing an estimated IRS position signal to a flight control when the GPS position signal is unreliable, the estimated IRS position signal being based upon the velocity of the vehicle, the acceleration of the vehicle and the IRS position signal.

16. The method of claim 15 wherein the velocity of the vehicle and the acceleration of the vehicle are monitored by the global positioning system.

17. The method of claim 15 wherein the velocity of the vehicle and the acceleration of the vehicle are monitored by the inertial reference system.

18. The method of claim 16 wherein the velocity of the vehicle and the acceleration of the vehicle are monitored by the inertial reference system.

19. The method of claim 15 further comprising the steps of:

determining if the estimated IRS position signal is reliable; and

providing an indication to a pilot of the vehicle if the estimated IRS position signal is not reliable.

* * * * *

Exhibit B

US006289277B1

(12) **United States Patent**
Feyereisen et al.

(10) **Patent No.: US 6,289,277 B1**
(45) **Date of Patent: Sep. 11, 2001**

(54) **INTERFACES FOR PLANNING VEHICLE ROUTES**

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(73) Assignee: **Honeywell International Inc.**, Morristown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/413,959**

(22) Filed: **Oct. 7, 1999**

(51) **Int. Cl.**[7] **G08G 5/04**; G06F 19/00
(52) **U.S. Cl.** **701/202**; 340/945; 342/109
(58) **Field of Search** 701/14, 24, 25, 701/26, 201, 202, 3, 301, 206, 200, 207, 4; 340/945, 947, 982, 983; 342/26, 109, 29, 455

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Primary Examiner—Tan Nguyen
Assistant Examiner—Dalena Tran
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(57) **ABSTRACT**

A system for producing vehicle routes such as aircraft flight plans in the presence of weather and other hazards defines static and moving hazards with polygons drawn on a display containing graphic hazard regions. Different hazard types and intensities are displayed differently. Both lateral and vertical geographic depictions are displayed, and hazards can be displayed temporally as well. Users input information and thresholds for hazards.

53 Claims, 3 Drawing Sheets

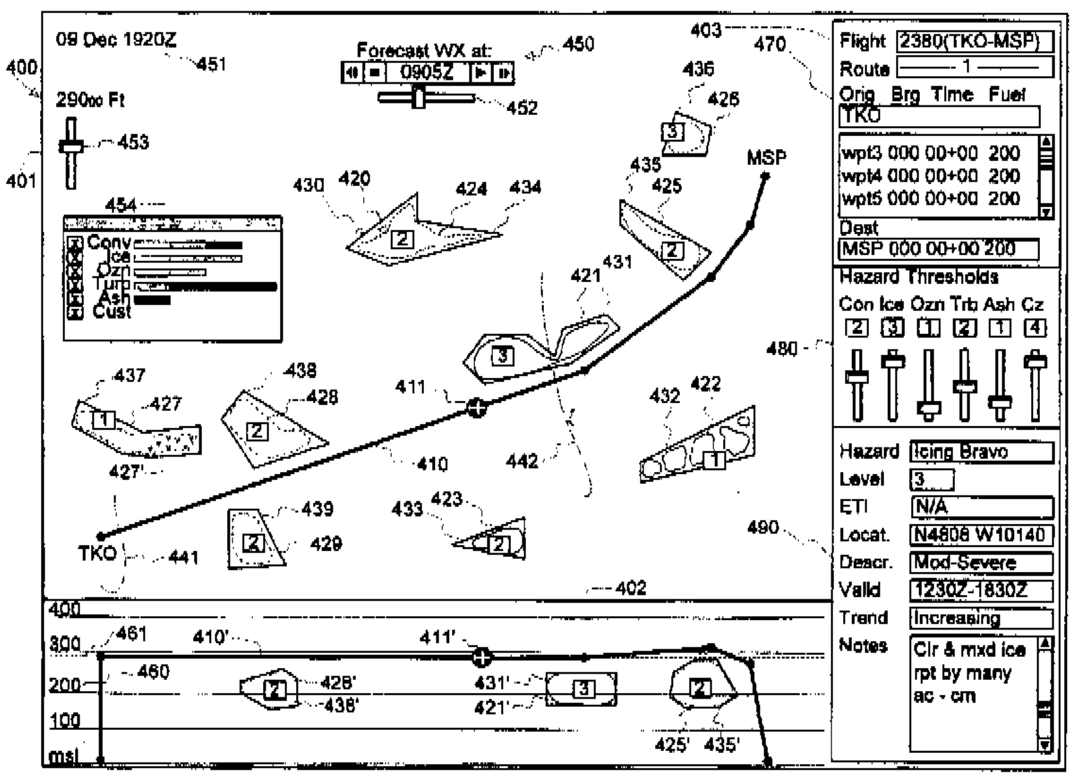
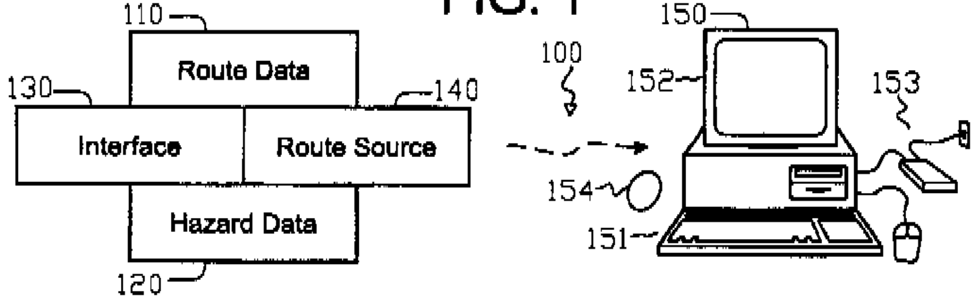


FIG. 1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Interface
Route Source
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Hazard Data
120
100
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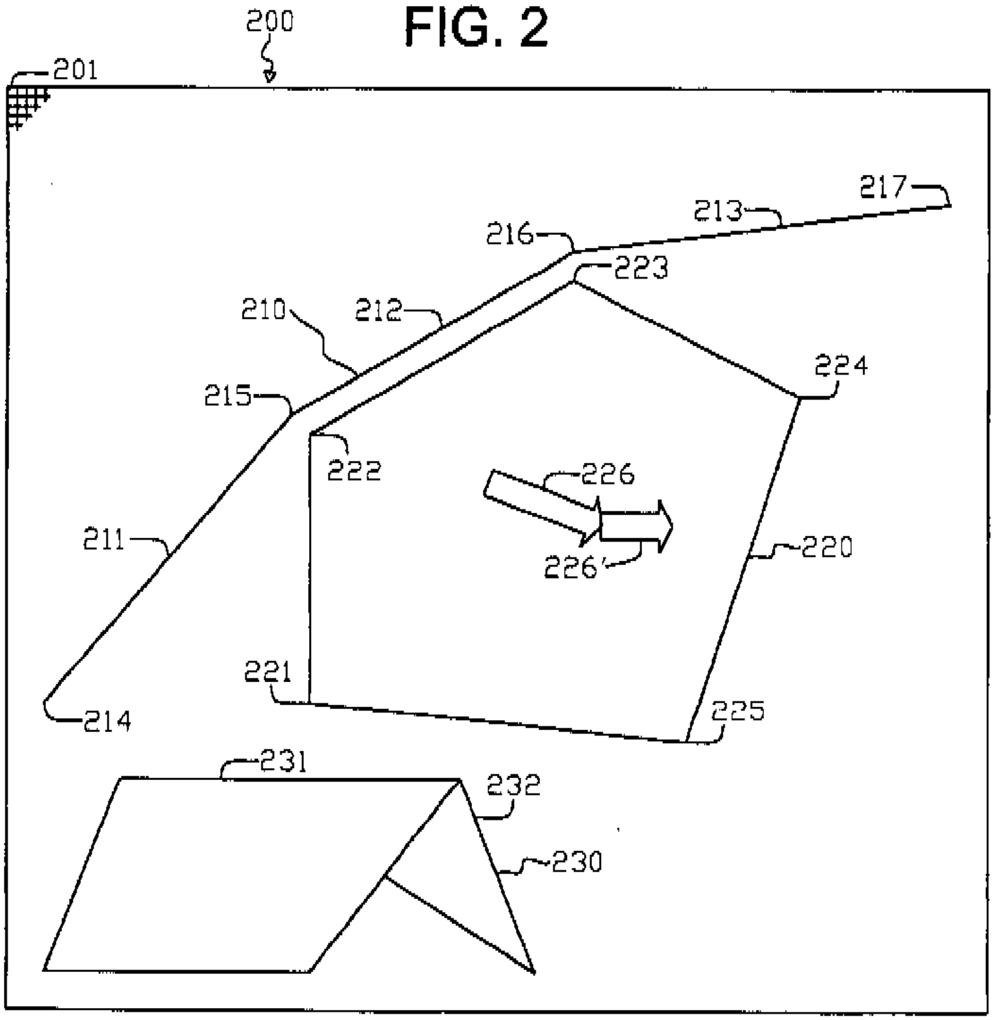
153
154
151

FIG. 2


200
201
217
213
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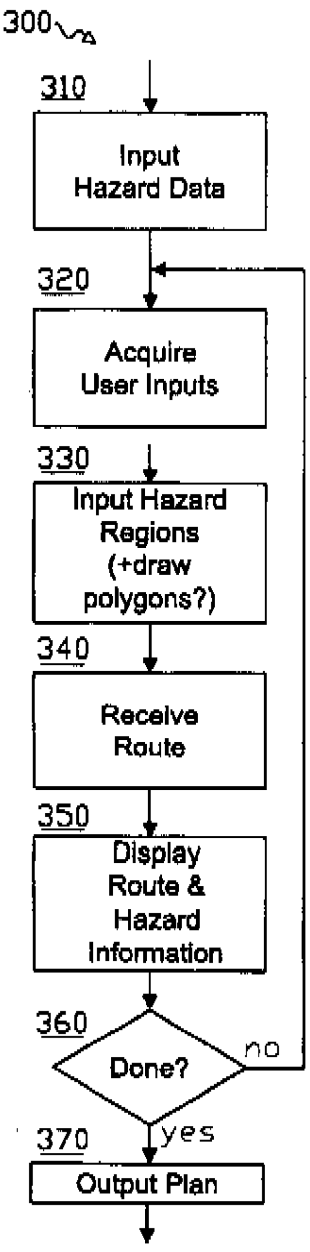
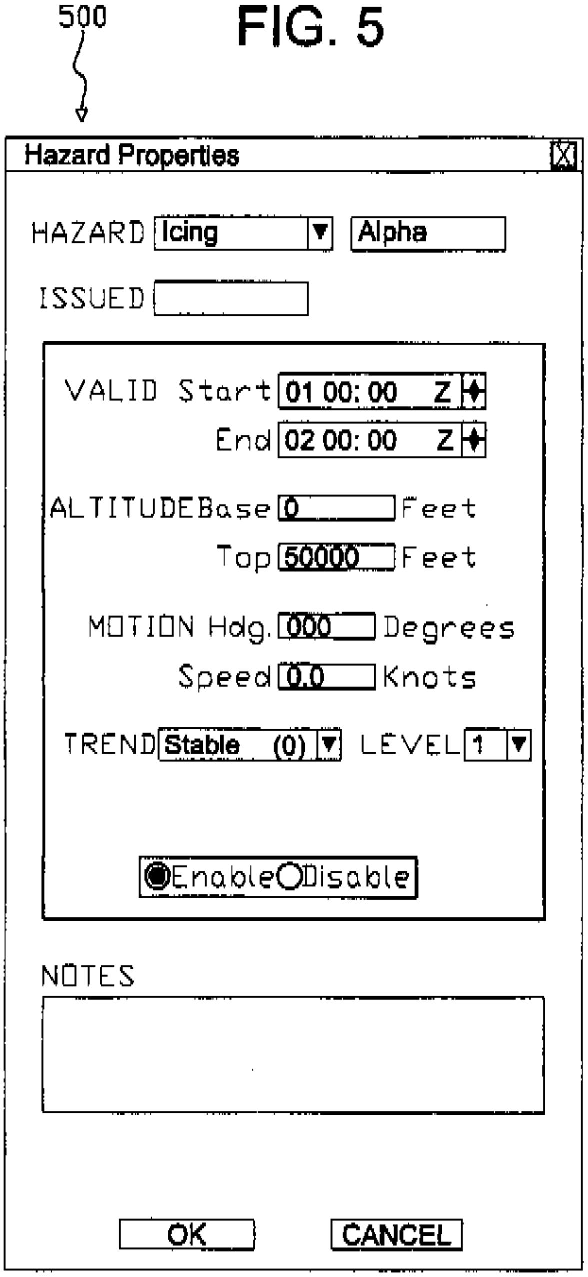
232
230

FIG. 3



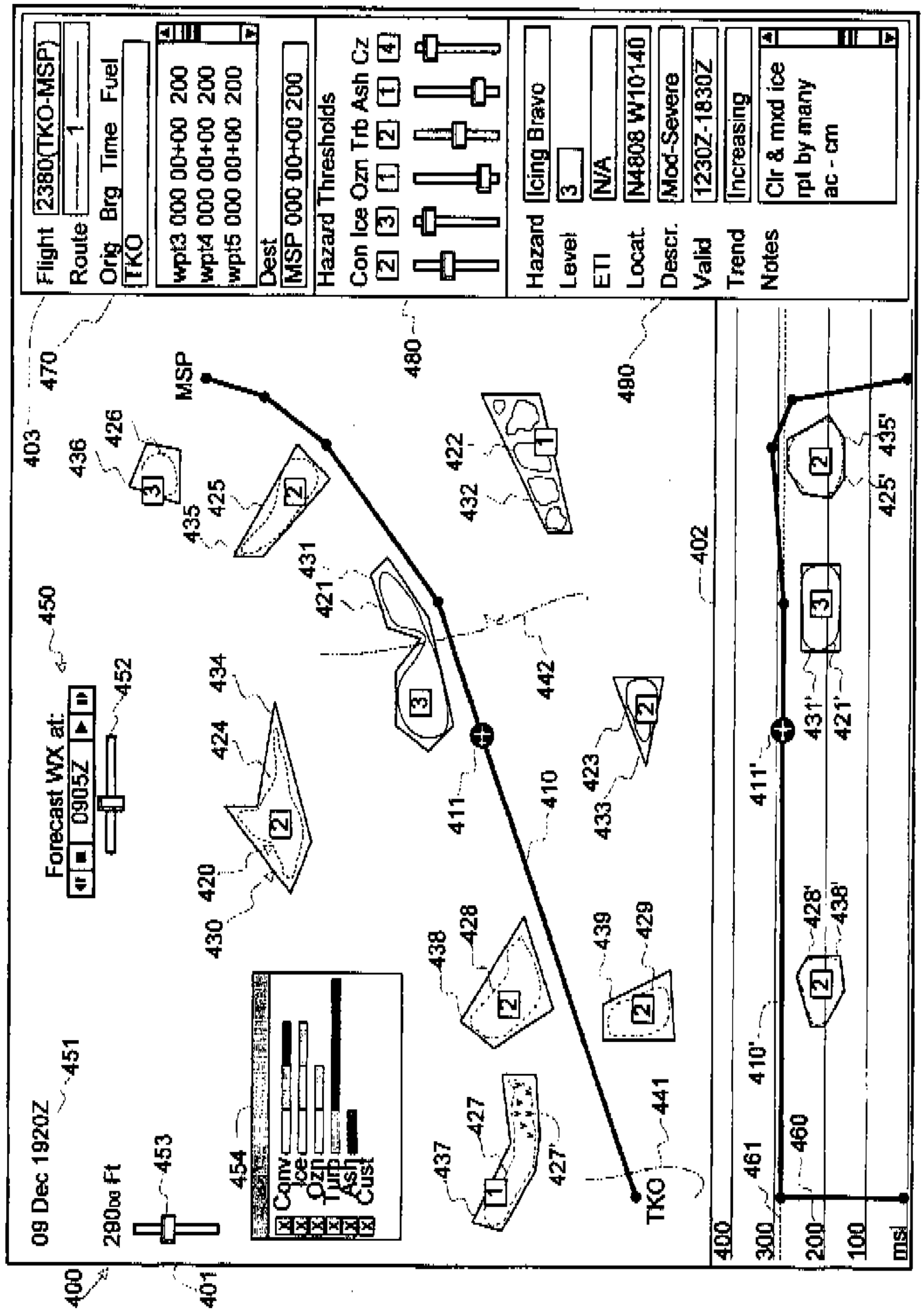
300
310
Input Hazard Data
320
Acquire User Inputs
330
Input Hazard Regions (+draw polygons?)
340
Receive Route
350
Display Route & Hazard Information
360
Done?
no
yes
370
Output Plan

FIG. 5



500
Hazard Properties
HAZARD
Icing
Alpha
ISSUED
VALID Start
01 00: 00 Z
End
02 00: 00 Z
ALTITUDE Base
0
Feet
Top
50000
Feet
MOTION Hdg.
000
Degrees
Speed
0.0
Knots
TREND
Stable (0)
LEVEL
1
Enable
Disable
NOTES
OK
CANCEL

FIG. 4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Orig Brg Time Fuel
TKO
wpt3 000 00+00 200
wpt4 000 00+00 200
wpt5 000 00+00 200
Dest
MSP 000 00+00 200
Hazard Thresholds
Con Ice Ozn Trb Ash Cz
2 3 1 2 1 4
Hazard Icing Bravo
Level 3
ETI N/A
Locat. N4808 W10140
Descr. Mod-Severe
Valid 1230Z-1830Z
Trend Increasing
Notes Clr & mxd ice rpt by many ac - cm
09 Dec 1920Z
290 Ft
Forecast WX at:
0905Z
Conv
Ice
Ozn
Turb
Ash
Cust
MSP
TKO
400
300
200
100
msl
400
401
402
403
410
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470
480
490
410'
411'
421'
425'
428'
431'
435'
438'

INTERFACES FOR PLANNING VEHICLE ROUTES

GOVERNMENT INTEREST

This invention was made with Government support under Cooperative Agreement No. NCC-1-291 awarded by NASA Langley Research Center. The Government may have certain rights in the invention.

TECHNICAL FIELD

The present invention relates to vehicle navigation, and more particularly concerns the planning of aircraft routes, including display and user interaction.

BACKGROUND

The aviation community has a goal of reducing the fatal-accident rate by eighty percent within the next ten years. At the same time, air traffic continues to increase, and the national airspace system is undergoing major changes. In particular, it is likely that aircraft pilots will be given more responsibility for avoiding hazards themselves.

Weather is a factor in a third of aircraft accidents. The National Aeronautics and Space Administration (NASA) is presently embarked upon a multi-year effort to provide better weather information and to improve hazard characterization, condition monitoring, data display, and decision support. At the present time, controllers, dispatchers, and air-traffic managers have access to a number of weather-information products from private vendors and from government services. Graphic displays of weather information on large airliners are limited to onboard weather radars and information from paper weather briefings. En-route updates are delivered either as voice messages via radio or as alphanumeric data-link printouts onboard the aircraft.

Flight planning is a complex task. A strategic planning and replanning tool produces a flight plan that describes the track, speed, and altitude that an aircraft will fly during various phases of an entire flight. Because the underlying models and assumptions made in a completely automated system may be incomplete or fallible, some have suggested the broad concept of a cooperative planner that interacts with a human operator. Pilots and dispatchers alike have stated that merely providing additional hazard information would not adequately support effective decision-making for routing choices. A need therefore remains for more advanced facilities for generating and modifying route plans for aircraft, both for increased safety and for better ease of use.

SUMMARY OF THE INVENTION

The present invention offers systems and methods for producing routes for aircraft and similar vehicles in response to a number of factors, including weather hazards and other in-flight conditions.

The invention offers systems and methods for interactive route planning in the face of weather and other hazards. It also furnishes data representations and models for factors that influence route planning, such as arrival time, fuel efficiency, passenger comfort, overflight fees, and conditions at terminals, including traffic congestion and closure of runways and other facilities. It further supplies an interface for facilitating the display of in-flight condition data and the manipulation of the route. It can optionally be used with a route optimizer for modifying computer-generated proposed routes.

The invention achieves these and other objectives by displaying hazards of different types in response to received data and defining boundaries and/or other specifications characterizing the hazards for purposes of the flight plan. Controls permit a user to modify the displayed data and to manipulate the route.

DRAWING

FIG. 1 is a high-level block diagram of a system according to the invention.

FIG. 2 is a schematic diagram showing data representations used in the invention.

FIG. 3 is a high-level flowchart showing the operation of the system of FIG. 1.

FIG. 4 is a diagram of a computer display for the system of FIG. 1.

FIG. 5 shows a properties box for the display of FIG. 4.

DETAILED DESCRIPTION

This description and the accompanying drawing illustrate specific embodiments in which the present invention can be practiced, in enough detail to allow those skilled in the art to understand and practice the invention. Other embodiments, including logical, electrical, and mechanical variations, are within the skill of the art. Other advantages and features of the invention not explicitly described will also appear to those in the art. The scope of the invention is to be defined only by the appended claims, and not by the specific embodiments described below.

FIG. 1 is a high-level block diagram of a system **100** for manipulating flight-plan information according to the invention. Block **110** is a structure for data representing a flight plan or intended route. Block **120** contains data representing one or more hazards associated with the flight plan. Computer program code **130** implements an interface for entering data into and displaying the data from blocks **110** and **120**. Route source **140** can be an optimizer containing computer program code for automatically generating flight plans to minimize a cost function that includes fuel, flight length, and/or other factors in the presence of hazards or other constraints. U.S. patent application Ser. No. 09/372,632, "Hazard Detection for Flight Plans and the Like," by Stephen G. Pratt and Gary L. Hartmann, hereby incorporated by reference, describes an example of such an optimizer. More generally, block **140** can be considered to be any source of flight plans, including standardized plan templates and plans entered manually in interface **130** by a user. Blocks **110–140** can form a part of a computer of any convenient type, general-purpose or special-purpose, such as the personal computer shown at **150**, having devices **151–153** for entering and displaying data. Some or all of the data may come from an external source such as a weather service, and is input to computer **150** via a communications device **153**. Code for implementing any of the functions of computer **150** may be represented on a medium such as signals from device **153** and/or stored on a medium such as a disk **154** external or internal to computer **150**.

FIG. 2 is a schematic of a geographical area **200** illustrating data used in system **100**. Flight plan **210** is represented as a sequence of segments **211–213** between preselected waypoints **214–217**. The waypoints have both horizontal and vertical parameters; each is defined by a latitude, a longitude, and an altitude. The flight plan can be created by an operations center, a dispatcher, or a pilot, or by a computer program such as optimizer **140**.

'Hazard' is a general term for any feature or condition to be avoided by the flight plan. Many of the significant hazards concern weather, e.g., convection, turbulence, and icing. Other atmospheric conditions include volcanic ash and stratospheric ozone concentrations. Political designations such as military training areas and areas having overflight fees or restrictions can also be considered to be hazards. Any condition that can be represented to system **100** can in fact be a hazard in the present context. Hazard data can come from any number of sources, including fixed-base and on-board weather radar, private and governmental operations, and aviation charts. The present system also permits a system operator to enter hazard data and types directly via interface **130**.

Hazards are instantiated as polygons such as **220**. Polygons have compact representations in terms of vertex points or edge lines. They can be easily transformed to represent movement; and they can be generalized easily to three dimensions. A hazard polygon is defined in terms of the latitudes and longitudes of its vertices **221–225**. The edges are great-circle connections between adjacent pairs of vertices. The number of edges is arbitrary. If desired, hazards can also be represented by polytopes (not shown) in three dimensions; the vertices then have altitude parameters as well. Hazard motion can be represented by a vector **226** that specifies the direction and velocity of the polygon's centroid. Additional vectors such as **226'** can be added in a sequence to define a path over a certain time interval. This embodiment simplifies calculations by requiring that all polygons be convex. However, more complicated shapes such as **230** can be constructed from multiple convex polygons **231**,**232**, etc. Each weather region or polygon also has an associated set of property data that includes the degree of its danger, such as severity, coverage, and forecast probability.

Because illustrative system **100** is a strategic planner that operates over an entire flight plan, the grid size **201** for representing features within area **200** varies with the length of the flight. In the interest of reducing calculations to a reasonable number, this embodiment is not constructed to thread its way through, say, one-km diameter convective cells on a coast-to-coast flight of 5000 km. Improvements in computing speed might, however, eventually allow the avoidance of individual small hazards, and even the integration of tactical aspects into the same system. The strategic nature of the system also results in prioritizing hazards that occur in the cruise phase of a flight. For example, although microbursts affect aircraft performance significantly, their effects usually occur at lower altitudes, in the take-off and landing phases, and they receive a lower level of attention in this implementation.

Some hazards, especially weather hazards, come in varying intensities. Rather than adding this complication to the process, this implementation considers only hazards that the operator considers dangerous, and permits the operator to set thresholds for different hazards, so that only those above the thresholds are displayed for consideration. This simplifies the data display for the user, allows more concrete control over an optimizer such as **140** through direct manipulation of the hazard boundaries, and permits clear visualization of routing decisions made by an optimizer. Moreover, sharp visible boundaries around hazards allow application of the same standards to multiple flights, and permit a user such as a dispatcher to better understand the effects of a (human or computer) routing decision for one flight on the operation of a fleet as a whole.

FIG. **3** shows the overall cycle **300** of system **100**, FIG. **1**. Block **310** acquires hazard data from an outside source such as those mentioned above. Block **320** acquires information from a user who manipulates interface **130** to create and delete hazard zones and types and to set thresholds for various types of hazard. Different flight conditions can be treated differently. For example, a cargo flight might elect to fly through a turbulent area that an airliner might wish to avoid in the interest of passenger comfort. Also, a pilot might decide to fly through an area of scattered convective activity and make small-scale lateral deviations to avoid isolated cells. On the other hand, an area of dense activity would be circumnavigated as a whole. There are common terms that can be employed for thresholding. For instance, 'isolated' activity refers to single cells, 'widely scattered' to activity occurring in 25% or less of an area, 'scattered' to up to 54%, and 'numerous' to 55% and more. Terms of probability are also in general use, such as 'slight chance' for 10–20% probability of precipitation, 'chance' for 30–50%, and 'occasional' for an activity that has at least 50% probability, but over less than half of the forecast period. These terms are not necessarily consistent among different conditions; e.g., 'occasional' turbulence occurs less than ⅓ of the time, while 'intermittent' occurs up to ⅔, and 'continuous' occurs above that amount. Some conditions are governed by airline policy, such as restricting passenger flights to altitudes below ozone concentrations above a toxic level. Other conditions, such as icing, are mandated for avoidance above certain levels. In addition, different icing restrictions apply to different aircraft; the present invention allows a dispatcher to set different restrictions such as icing on an aircraft-by-aircraft basis.

Block **330** generates the boundaries of hazard polygons such as areas **220** and **230**, FIG. **2**, from the information provided by blocks **310** and **320**. Again, restricting the boundaries to convex polygons (or polytopes) simplifies calculations for the optimizer, but is not a requirement for the concept. Block **340** receives data representing a route. As noted above, routes can come from many different sources: an optimizer such as **140**, a stored library of plans, or directly from a user input through interface **130**. Block **350** displays the hazard areas and the computed flight plan via interface **130**. Block **360** then iterates the cycle if the user so desires. Block **370** outputs information **110**, FIG. **1**, concerning the flight plan.

FIG. **4** shows a computer display **400** for interface **130**, FIG. **1**. Area **401** contains lateral schematic representations of route data **110**, hazard data **120** on a background of geographical and other data useful for context. Area **402** is a representation of the route and hazard data in a vertical slice through the route. Area **403** contains representations of standard control icons for manipulating data representations in area **401**. Display **400** integrates human factors and human-centered design strategies for ease of operation. The design of this embodiment uses current conventions adopted in the aircraft industry in order to maintain uniformity where feasible, but is not limited to those conventions where they do not serve the functionality of the present system. The overall display follows the "dark cockpit" philosophy that advocates subdued colors for normal operation, in order to reduce eyestrain and increase readability across a range of environmental conditions. Black is employed as a background color for the displayed elements, as is almost universal in aviation instrumentation. (FIG. **4** uses colors better adapted to clarity of exposition.)

Area **401** includes a map-like plan or lateral depiction of the geographic area of the flight, in this example, from Tokyo Narita (TKO) airport to Minneapolis-St. Paul Lindbergh (MSP) airport. For large geographic areas, the lateral depiction follows a modified conical projection, as employed by World Aeronautical Charts (WAC).

A proposed flight-plan route **410** has segments between a number of waypoints, shown respectively as heavy lines and small filled circles in FIG. **4**. The data display does not directly show the altitudes of the waypoints in this view. Symbol **411** shows the aircraft position at the current time index. Multiple routes (not shown) can be displayed simultaneously, if desired, by using characteristics such as stippling to differentiate them from each other. A user can manipulate flight plan **410** by inserting mandatory or constrained waypoints, and by moving or deleting waypoints. Conventional clicking and dragging operations with a data-entry device **151** such as a mouse can realize such functions. The term "mouse" should be taken broadly to include any kind of cursor-positioning device, such as a trackball, joystick, etc.

Regions indicated collectively as **420** display the various types of hazards or other conditions to be avoided. The boundaries of hazards are shown by irregular lines. In the actual display, various types of hazards are shown in different colors or hues that are shaded to indicate severity. Specific colors and shades are selected to enhance visibility in the specific environment. For example, lighter shades indicate higher severity levels in display **400** in order to enhance contrast with the choice of a dark background. Also, because weather phenomena tend to occur in the same vicinity, hazard areas frequently cluster on the display. The drawing order of hazard regions therefore follow an assigned order of importance: volcanic activity highest, then level-3 convective activity, level-3 icing, level-4 turbulence, and level-2 ozone lowest. Color transparency (i.e., alpha axis) also facilitates the perception of multiple elements such as weather and land that might occur in the same location. Also, as described below, the operator can filter various phenomena to view only those of current interest. Display **400** includes all severity levels of the hazards, although some levels could be filtered out if desired. FIG. **4** depicts three illustrative kinds of hazard with different patterns on their boundary lines to symbolize the different colors: solid lines indicate convective weather, as at **421**–**423**; dashed lines **424**–**426** are icing; and dot-dash lines **427**–**429** are turbulence. The boxed numerals associated with each region indicate the severity and/or probability of the hazard. A visual effect such as varying amounts of stippling could be used as at **427'** to indicate greater or lesser areas of coverage of a hazard within the defined boundary.

Polygons or other boundaries **430** enclose hazard regions **420**. An operator draws individual polygons **431**–**439** by selecting and dragging points with a mouse or other input device. Hazard polygons can also be drawn by operators other than the one constructing the flight plan, and can be automatically generated by a source that provides hazard information to system **100**. Such hazards can also include properties in files that produce properties boxes. Some or all of this information can be included as default or nominal values.

A direction and/or rate of travel can be imparted to the polygon by selecting the center of the polygon and dragging a vector. A path of multiple successive vectors can also be entered. A single polygon can enclose multiple weather regions; polygon **432**, for example encapsulates a squall line having multiple cells that are considered so closely spaced as to prohibit penetration of the entire region. Hazards other than those built into the system can be defined and entered as a "custom" type.

The operator can open a properties box for a polygon by double-clicking the polygon. FIG. **5** shows an example **500** of such a properties box. The operator can enter information associated with the hazard, including a name, a severity level, a description, times during which the hazard is valid, vertical dimensions, and notes. For moving hazards, the properties can include:

- An initial time value, at which the drawn vertices represent the position of the hazard. Typically this time value is in the future, and the vertex points incorporate weather-model or other forecast information.
- The position of a point that represents the center of motion of the hazard polygon.
- The heading and speed of the polygon's motion at the center position. The motion occurs along a great circle rather than along a rhumb line, so the direction changes over large distances.

Because hazard polygons move along great-circle paths, the display program transforms its coordinates from earth frame into a reference frame that coincides with the great circle, rotates it at an angle corresponding to the distance traveled at its specified speed, then transforms the coordinates back to the original earth frame for presentation in area **401**. This embodiment employs a constant shape for moving hazard polygons. However it is possible to define multiple shapes for different times if desired. It is also possible to vary course, speed, and other properties over time if the added complexity is worthwhile.

Area **401** can also show geographic, topographical, political, and other features. Partial lines **441** and **442**, for example, indicate coastlines for landmasses rendered in subdued transparent colors.

Area **401** can also include some data and control icons **450**. Legend **451** shows the date and time of the flight. Movie-player control **452** of a conventional type indicates the current time index for depicting the positions of hazard shapes **420** and **430**, and of aircraft symbol **411**. The associated slider varies the time index under operator control, and the flight plan can be played through time with the conventional recorder-type buttons, thus animating the moving hazards and aircraft symbol. The buttons select continuous play, pause, beginning, and end. Control **453** shows and modifies the altitude of the horizontal slice of airspace being shown in area **401**; full slider displacement shows all altitudes.

Floating window **454** contains controls and color/shading conventions for the various types of hazards. The text labels name the hazard types, and include an operator-defined 'custom' type. The bars represent the hue used to designate each type of hazard in regions **420** and polygons **430**, and the shadings used to indicate different severity levels of each hazard. (For clarity, color designations have been omitted from the regions and polygons in FIG. 4.) The check-boxes in window **454** permit an operator to select whether hazards of the corresponding type are to be displayed or not.

Area **402** is a vertical depiction of the route, taken through a slice along the segments of flight plan **410'**, and includes the waypoints and aircraft position indicator **411'**. The vertical scale is exaggerated greatly over the horizontal scale. Light horizontal lines **460** denote altitude increments above mean sea level, marked in flight levels (i.e., hundreds of feet). The level of dashed line **461** is set by the altitude slider of control **453**. The vertical projections of hazard areas **421'**, **425'**, and **428'** and their polygons **431'**, **435'**, and **438'** that intersect route **410'** are shown in area **402**.

Area **403** contains data values and control structures that affect the flight plan. General information identifying the flight and a route iteration number are contained in general-information cluster **470**. The operator can select a flight, and select among several alternative routes with drop-down combination boxes. This subarea also includes information concerning the origin, destination and waypoints. A scroll-box contains information relating to waypoints, such as their names ("wpt3," etc.), bearings, estimated times en route, and remaining fuel. The user can enter required times of arrival (RTA), altitudes, and other constraints here as well. Threshold cluster **480** includes sliders for permitting an operator to set threshold severity values for a number of different types of hazard, such as convective weather ("Con"), icing ("Ice"), ozone concentrations ("Ozn"), turbulence ("Trb"), volcanic ash ("Ash") and custom zone ("Cz"). Recommended maximum values appear in boxes above their respective sliders. A user drags the sliders to set threshold values that the user wishes the flight plan to avoid. These values can be communicated to optimizer **140**.

Subarea **490** contains information regarding one of the hazard regions **421**–**429**, in response to a single mouse click over its corresponding polygon **431**–**439**. FIG. **4** shows the information for region **426**, named "Icing Bravo" in the top entry of subarea **490**. Other entries show a severity level and an estimated time of intercept with the flight path, the location of the center of the hazard polygon, the range of severity levels found within the hazard region, a time block during which the hazard exists, and the severity trend of the hazard. Users can enter time-stamped notes at the bottom of the subarea. Some of the other entries can also be edited by direct entry of data, although some are prohibited and others are constrained to certain data values. In the latter case, clicking and holding on the text field of an entry elicits a drop-down menu of possible values for that entry. Clicking and holding on the "Hazard" entry produces a drop-down of the names of all the displayed hazards, plus a "New Hazard" choice for adding a hazard to the display. Selecting any of the choices in the "Hazard" drop-down list also generates a properties box **500** for that hazard in area **401**.

CONCLUSION

The invention presents systems and methods for displaying and manipulating routes for aircraft and other objects in the presence of hazards. Many variations and generalizations within the scope of the invention will occur to those skilled in the art. In particular, the term "flight plan" must be taken broadly to include routes for other vehicles, and similar plans for maneuvering in the presence of hazards. Likewise, hazards are broadly defined as conditions that might affect the plan of the route. Hazards can, for example include political and other zones in addition to weather and similar phenomena. This term can include regions that might be more desirable than surrounding regions (i.e., have a negative cost), rather than only regions that should be avoided entirely. Some hazards can be other than regions having a geographic extent or physical boundaries; for example, some intermediate stops might impose landing fees that increase the overall cost of a flight. Hazard boundaries or other designations can be indicated other than by polygons or other linear structures. Multiple nested polygons could represent different costs associated with different levels of a hazard region. The division of the described systems and methods into blocks in the above description does not imply that other divisions are not possible or desirable. Indications that some components or steps are convenient or preferred does not imply that others might not be desirable or within the scope of the claims. The sequence of blocks in the description and of recitations in the claims does not imply any particular time order.

We claim as our invention:

1. A method carried out by a programmed computer for planning routes by a user in the presence of hazards, comprising:

receiving data representing a proposed route for a vehicle;

receiving data representing hazards associated with the route, the hazards having a plurality of different types;

displaying geographic representations of the route data and the hazard data together in the same presentation, the different types of hazards being represented differently from each other; and

inputting specifications from the user for modifying the displayed representations of specified portions of the hazard data.

2. The method of claim **1** where the route is a flight plan for an aircraft.

3. The method of claim **2** where the flight plan includes a plurality of waypoints.

4. The method of claim **1** where the specifications include boundaries of areas representing at least one of the hazards.

5. The method of claim **4** where the boundaries are polygons.

6. The method of claim **1** where the specifications include data relating to motion of at least one of the hazards.

7. The method of claim **6** where the data relating to motion comprises direction and speed of the one hazard.

8. The method of claim **6** further comprising varying the time at which the hazards are depicted in the display.

9. The method of claim **1** where hazard types include weather hazards.

10. The method of claim **9** where the displayed hazard data represents different hazard intensities differently.

11. The method of claim **1** where the geographic representations are displayed in a lateral depiction.

12. The method of claim **1** where the geographic representations are displayed in a vertical depiction.

13. The method of claim **1** where inputting the specifications from the user comprises receiving inputs from a set of controls operable by the user.

14. The method of claim **13** where the controls include a control for varying the time at which the hazards are depicted in the display.

15. The method of claim **13** where the controls include at least one control to establish a threshold for an intensity of a hazard to be avoided by the route.

16. The method of claim **1** further comprising producing the received route data by optimizing a cost function for the route.

17. A medium containing program instructions for causing a suitably programmed digital computer to carry out a method for planning routes in the presence of hazards, the method comprising:

receiving data representing a proposed route for a vehicle;

receiving data representing hazards associated with the route, the hazards having a plurality of different types;

displaying geographic representations of the route data and the hazard data together in the same presentation, the different types of hazards being represented differently from each other; and

inputting specifications from the user for modifying the displayed representations of specified portions of the hazard data.

18. The medium of claim **17** where the medium comprises a storage medium.

19. The medium of claim **17** where the medium comprises signals.

20. A computer-implemented system for planning routes in the presence of hazards, comprising:

data representing a route for a vehicle;

data representing hazards with respect to the route, the hazards having a plurality of different types; and

an interface including

a geographic display of the hazard data and the route data together in the same presentation the different types of hazards being represented differently from each other, and

controls for manipulating the route data and the hazard data, and for inputting specifications for modifying the displayed representations of data associated with at least some of the hazards.

21. The system of claim **20** where the vehicle is an aircraft.

22. The system of claim **20** where the specifications include boundaries of areas representing at least one of the hazards.

23. The system of claim **22** where the boundaries are polygons.

24. The system of claim **20** where the specifications include data relating to motion over time of at least one of the hazards.

25. The system of claim **24** where the data relating to motion comprises direction and speed of the one hazard over time.

26. The system of claim **20** where the route data includes data for a plurality of alternative routes.

27. The system of claim **20** where the route data includes a plurality of waypoints.

28. The system of claim **20** where hazard types include weather hazards.

29. The system of claim **28** where the displayed hazard data represents different hazard intensities differently.

30. The system of claim **20** where the geographic representations are displayed in a lateral depiction.

31. The system of claim **20** where the geographic representations are displayed in a vertical depiction.

32. The system of claim **20** where inputting the specifications from the user comprises receiving inputs from a set of controls operable by the user.

33. The system of claim **32** where the controls include a control for varying the time at which the hazards are depicted in the display.

34. The system of claim **32** where the controls include at least one control to establish a threshold for an intensity of a hazard to be avoided by the route.

35. The system of claim **20** further comprising an optimizer for producing the received route data.

36. Apparatus for manipulating a flight plan by a user, comprising:

means for receiving data representing an aircraft route;

means for receiving data representing hazards with respect to the route;

means for a user to input specifications of area boundaries to be associated with the hazards; and

means for presenting geographic representations of the route data, the hazard data, and the boundaries.

37. The apparatus of claim **36** where the apparatus comprises a programmed computer.

38. The apparatus of claim **36** where the presenting means includes a visual display.

39. The apparatus of claim **36** where the input means includes a cursor-positioning device.

40. The apparatus of claim **36** where the hazard receiving means includes a communications device.

41. The apparatus of claim **36** further comprising an optimizing means for minimizing the cost of the route in response to the specifications input by the user.

42. A computer-implemented system for planning routes **(410)**, in which data **(110)** associated with a route and data **(120)** associated with hazards are represented on an interface **(130)**,

characterized in that the interface displays the route data and the hazard data together geographically **(401, 402)** and includes controls **(450, 480)** for manipulating the displayed route **(410)** and hazards **(420)**.

43. A system according to claim **42**, characterised in that the user controls include boundaries **(430)** of areas representing at least one of the hazards.

44. A system according to claim **43**, characterized in that the boundaries are polygons.

45. A system according to claim **43**, characterised in that the user controls include motion parameters **(226)** of at least one of the hazards.

46. A system according to claim **42**, characterised in that different types of weather hazards are displayed differently.

47. A system according to claim **42**, characterised in that different intensities of the same weather hazards are displayed differently.

48. A system according to claim **42**, characterised in that the user can set a number of thresholds for different types of the weather hazards.

49. A system according to claim **42**, characterized in that the geographic display is a lateral depiction **(401)**.

50. A system according to claim **42**, characterized in that the geographic display is a vertical depiction **(402)**.

51. A system according to claim **42**, characterized in that the hazard data is displayed temporally as well as geographically.

52. A system according to claim **42**, characterized in that the route data is optimized while avoiding at least certain of the hazards.

53. A system according to claim **52**, characterized in that the route data has a minimum cost function with respect to certain factors.

* * * * *

Exhibit C

US006308132B1

(12) **United States Patent**
Wilson et al.

(10) **Patent No.: US 6,308,132 B1**
(45) **Date of Patent: Oct. 23, 2001**

(54) **METHOD AND APPARATUS FOR DISPLAYING REAL TIME NAVIGATIONAL INFORMATION**

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(73) Assignee: **Honeywell International Inc.**, Morristown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Jun. 13, 2000**

(51) **Int. Cl.**^{7} **G08G 5/04**

(52) **U.S. Cl.** **701/200**; 701/208; 701/213; 340/990

(58) **Field of Search** 701/200, 201, 701/206, 208, 212, 213; 340/988, 982, 990, 995, 825.15

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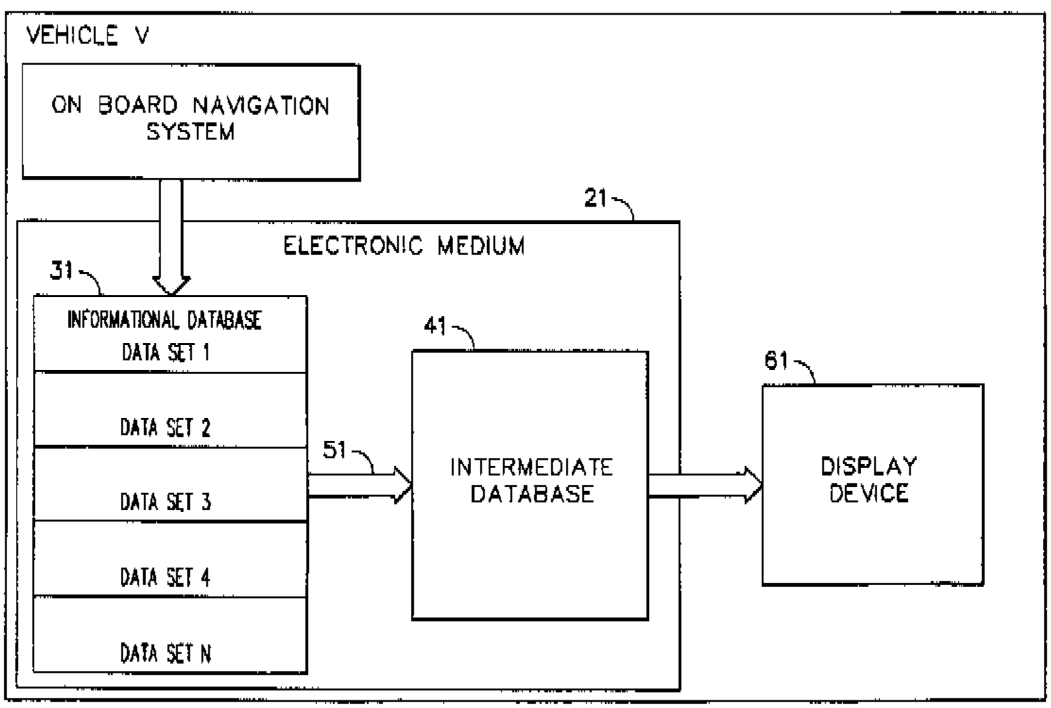
Primary Examiner—Richard M. Camby

(57) **ABSTRACT**

A method and apparatus for displaying real time navigational information on a vehicle including an informational database which is loaded and stored on an electronic medium within the vehicle. An intermediate database is created from the informational database and stored on the electronic medium. The contents of the intermediate database are transmitted to a color display unit for continuous real time display to the vehicle's operator based upon a desired reference point. In one embodiment, the intermediate database is created by fusing preselected information from the informational database and projecting the preselected information to correspond to a common graphical coordinate axis. In another embodiment, the intermediate database is created by each intermediate database created by spatially and coordinately culling the informational database to obtain spatial data stored on the electronic medium, filtering the spatial data by the software means to obtain displayable data corresponding to a geographic vicinity of a desired reference point and projecting the displayable data to a mapping system which contains a common graphical coordinate axis based upon the desired reference point.

26 Claims, 1 Drawing Sheet



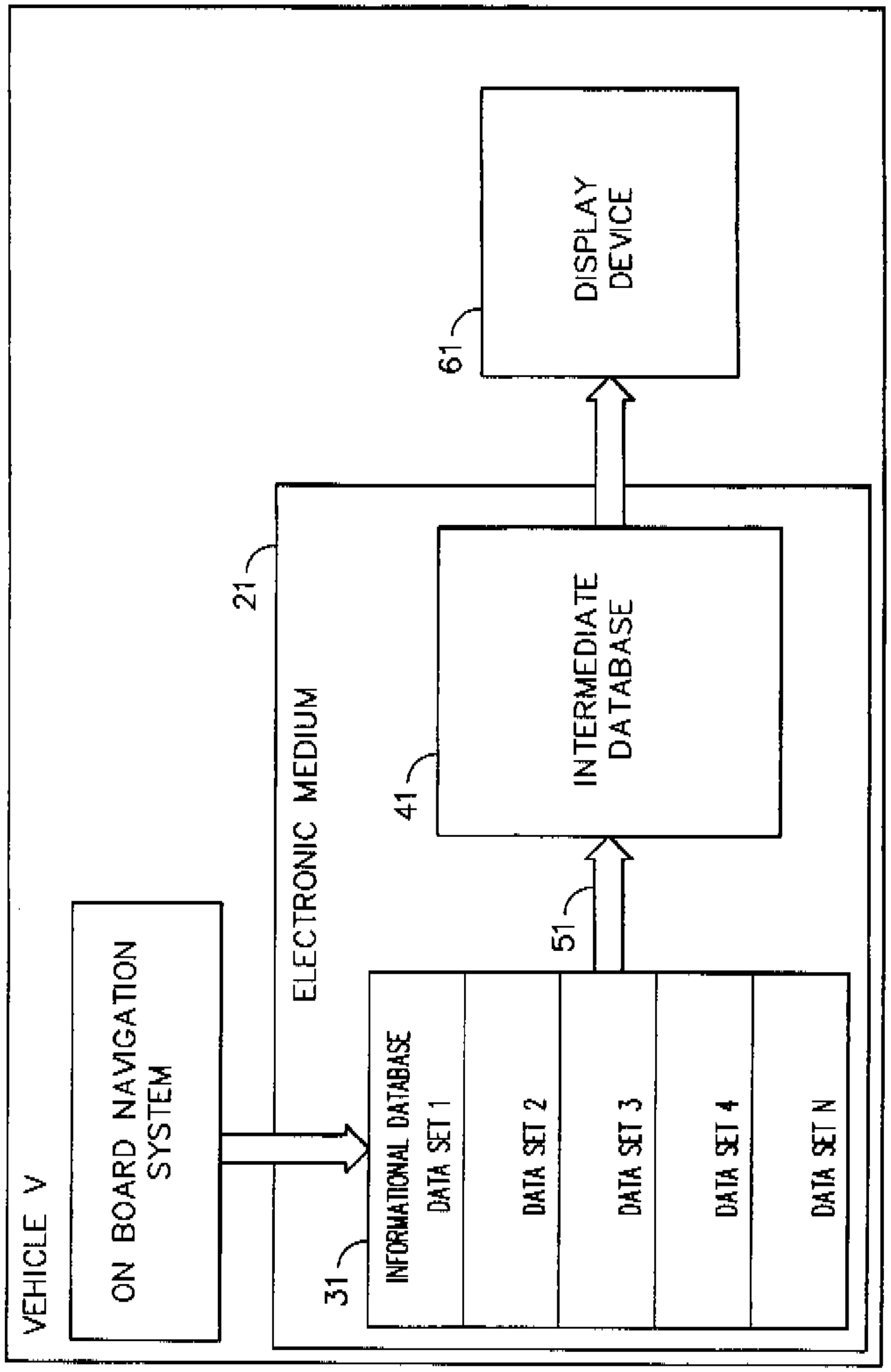

VEHICLE V
ON BOARD NAVIGATION SYSTEM
ELECTRONIC MEDIUM
21
31
INFORMATIONAL DATABASE
DATA SET 1
DATA SET 2
DATA SET 3
DATA SET 4
DATA SET N
51
41
INTERMEDIATE DATABASE
61
DISPLAY DEVICE

FIG. 1

METHOD AND APPARATUS FOR DISPLAYING REAL TIME NAVIGATIONAL INFORMATION

FIELD OF THE INVENTION

The present invention relates to the field of navigational instrumentation for a vehicle.

BACKGROUND OF THE INVENTION

In the prior art, operators of various navigable vehicles (such as aircraft pilots, for example) relied heavily on printed maps and single unit instrumentation to determine a vehicle's coordinate location relative to some reference point. One problem with printed maps, however, is that printed maps do not provide an accurate representation of coordinate location on the earth due to the curvature of the earth. Thus, an airplane pilot who relied on printed maps to determine location knew or should have known that any location determined from the printed maps was only an approximation and not an accurate representation of the vehicle's coordinate location. At one time the maps in use were generally better than the available navigation accuracy, but, printed charts required a concentrated effort to use.

As technology advanced, so did the tools by which the pilots determined their location. One technology, for example, is the very high omnirange (VOR) system, which includes a collection of navigation beacons or lights positioned on the ground which would allow pilots to position themselves relative to each beacon. Other tools, such as global positioning satellite systems, became available to also assist pilots in navigation, and were integrated into the instrumentation of the vehicle's navigational system. Additional tools include enhanced ground proximity warning systems (EGPWS), which is a radar-based tool combined with a database of terrain that keeps track of the location of an airplane and the ground terrain relative to each other, and further, provides an audible warning of when the airplane is close to the ground and thus, close to impact. The EGPWS would also briefly display an obstacle threat (such as a upcoming mountain) as a threat warning, but in some cases, it did not provide sufficient time to allow the vehicle's operator to guide the vehicle in a safer direction.

Another tool which has been implemented in some airplanes is known as the flight management system (FMS), which included a textual display unit which displayed limited information corresponding to navigational parameters of concern by the vehicle's operator (such as airport location, navigation aids and navigation aids). The FMS was deficient because it was not designed to display other information which may be important to the safety of the vehicle's occupants and operation of the vehicle, such as weather data including areas of known wind shear, icing, wind speed, wind direction and like data. Further, the FMS system is manually intensive and slow, requiring the vehicle's operator to input commands into an on-board keyboard, having a processor execute the commands and then slowly refreshing the FMS display screen.

Until the present invention, the prior art was void of a method or apparatus for displaying real time navigational information on a single, display unit within a vehicle having a navigational system, the information generated from a number of information sources stored in at least one database (including information relating to environmental terrain data, obstacle data, adjacent vehicle data, special use airspace data, political boundaries, state boundary lines, geographic features, navigation aids, airport information

data, airway and intersection data, weather data, cultural data, man-made object data, air traffic data, wind data and flight plan data). One reason that such a tool did not exist was because computing power was not sufficiently advanced to handle the large amount of calculations required, and further, because the cost of memory available to store and manipulate significant amounts of data was expensive. Moreover, some information (such as, for example, accurate terrain and geographic data) did not exist. The present invention solves this gap in prior art technology by providing a method and an apparatus for displaying real time information which, in one preferred embodiment, is coupled to a vehicle's navigation system.

Accordingly, it is an object of the present invention to provide a method and apparatus for integration with a vehicle's navigation system, the method and tool displaying continuous information relating to environmental terrain, potential obstacles in the path of the vehicle, nearby vehicles, special use airspace, political and state boundary lines, geographic features such as rivers and lakes, navigation aids, airports and information relating to airports, airways and intersections, weather, cultural features such as highways, cities and high-tower lines or towers, proposed flight paths, wind direction and speed, drift down area and air traffic information.

It is also an object of the present invention to provide a method for displaying continuous information relating to environmental terrain, potential obstacles in the path of the vehicle, nearby vehicles, special use airspace, political and state boundary lines, geographic features such as rivers and lakes, navigation aids, airports and information relating to airports, airways and intersections, weather, cultural features such as highways, cities and high-tower lines or towers, a proposed flight path, wind direction and speed, drift down area and air traffic information on a single navigational display unit.

It is also an object of the present invention to provide a method and apparatus which communicates with both a vehicle's onboard navigational system and external offboard information sources, integrates the information from the system and external sources, and then continuously displays selected information of concern by the vehicle's operator on a single display unit.

BRIEF SUMMARY OF THE INVENTION

The following summary of the invention is provided to facilitate an understanding of some of the innovative features unique to the present invention, and is not intended to be a full description. A full appreciation of the various aspects of the invention can only be gained by taking the entire specification, claims, drawings, and abstract as a whole.

The present invention is a method and apparatus for real time navigational display for a vehicle including an informational database which is loaded and stored on an electronic medium (such as, for example, a personal computer) within the vehicle. An intermediate database is created from the informational database and stored on the electronic medium. The contents of the intermediate database are then transmitted to a multicolor display unit for continuous display to the vehicle's operator based upon a desired reference point. In one embodiment, the intermediate database is created by fusing preselected information from the informational database and projecting the preselected information to correspond to a common graphical coordinate axis.

The novel features of the present invention will become apparent to those of skill in the art upon examination of the following detailed description of the invention or can be learned by practice of the present invention. It should be understood, however, that the detailed description of the invention and the specific examples presented, while indicating certain embodiments of the present invention, are provided for illustration purposes only because various changes and modifications within the spirit and scope of the invention will become apparent to those of skill in the art from the detailed description of the invention and claims that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying figure further illustrates the present invention and, together with the detailed description of the invention, serve to explain the principles of the present invention.

FIG. 1 is a graphical representation of one embodiment of the present invention, correspond to both the method and apparatus claims according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention concerns a method and apparatus for continuously displaying selected navigational information on a single display unit within a vehicle V having a navigational system. In one embodiment, as seen in FIG. 1, the present invention includes an electronic medium 21 (such as, for example, a computer, a processor or a like device) in communication with the vehicle's V navigational system. The electronic medium 21 further includes memory storage space (not shown) for storage of database records. An informational database 31 is thus generated, loaded and stored on the electronic medium. The informational database 31 contains various preselected static and dynamic information arising from various sources. For example, the informational database 31 may contain information or data corresponding to weather radar, traffic collision and avoidance systems, known global terrain or geographic data (including a computer model of the surface of the earth), known obstacle data, special use airspace data, political boundaries, state/city/county or other civic boundary lines, geographic features (such as, for example, rivers, lakes or the like), navigation aids, airport information data, airway and intersection data, weather data, cultural data, man-made object data and air traffic data. Some of this information may be static information (such as, for example, known global terrain data) which will not change during the vehicle's operation and therefore, does not require constant updating, while other sources of information may be dynamic information that is dynamically updated on a real time basis (such as, for example, weather information or adjacent vehicle information) which will likely change as the vehicle is operated. Thus, those of skill in the art will realize that static information can be loaded and stored in the electronic medium 21 when the vehicle V is not in use or when the vehicle V in being maintained, whereas dynamic information can be updated and stored in the electronic medium 21 by other on-board navigational systems while the vehicle V is being operated.

Once the informational database 31 is created and stored on the electronic medium 21, an intermediate database 41 is created by a software means 51 which is loaded, stored and executed on the electronic medium 21. In one embodiment, the software means 51 creates the intermediate database 41

by initially fusing (or, collecting) preselected information from the informational database 31 and subsequently projecting (or, mapping) such preselected information to a mapping system which contains a common graphical coordinate axis which is based upon a desired reference point (such as, for example, the aircraft or a specific geographical coordinate location). In this regard, the preselected information or portions of the preselected information can be displayed in the vicinity of the reference point on the display device 61. This projection technique is required to account for the fact that planar (or, flat) surface maps are distorted because such planar maps cannot accurately depict a curved surface (such as the curvature of the earth).

In another embodiment, the software means 51 creates the intermediate database 41 by employing a processing technique which allows preselected records from the intermediate database to be displayed continuously on the display device 61. Thus, the software means 51 initially employs spatial culling so that data from the informational database are stored as a spatially sorted data structure by geographic location. Other data may also be eliminated based on the map area to be displayed. Next, the software means 51 filters the spatially stored data to obtain displayable data corresponding to the vicinity of the desired reference point (such as, for example, the location of an airplane relative to the earth or a particular geographic location on earth). The displayable data is slightly larger (for example, five to six times larger) than the data required to be displayed on the display device 61 so that the geometry represented by the displayable data can be used to continually render multiple display frames on device 61 which significantly reduces computational processing. Finally, the displayable data is projected to a mapping system which contains a common graphical coordinate axis which is based upon the desired reference point.

Most planar maps are depicted in latitude and longitude units. While such planar maps suffice to provide generalized geographic location information, such maps are heavily relied upon despite the fact that an accurate geographic location cannot be rendered (especially for those geographic locations near the north or south poles). Thus, planar map information must be projected (or, mapped) into a common coordinate system to account for the earth's curved surface. While various methods for projecting this information exist, all methods distort the final map in one way or another. However, by projecting the planar map information into a common coordinate system, the present invention significantly reduces or completely eliminates such distortion, near the center of projection.

In one preferred embodiment of the present invention, the common coordinate system is created by the software means 51 by transforming all latitude and longitude information which may exist in the informational database 31 into nautical mile information. By applying this transformation technique, a common graphical coordinate axis can be generated from the records among the various informational database 31 used. As those of skill in the art will come to realize, this projection technique allows for the creation of a common view which keeps nautical miles square. This technique substantially prevents or eliminates distortion from occurring in real time at or near the desired point of reference.

Once the intermediate database 41 is created and stored on the electronic medium 21, selected records from the intermediate database 41 can then be transmitted to a single graphical multicolor display device 61 for viewing by the vehicle's operator. The display device 61 is adapted to render the selected records from the intermediate database 41 graphically and continuously. Further, the display device is programmed to present text information in a right-side-up view relative to the vehicle's operator regardless of the vehicle's path. The display device 61 is also programmed to display known hazardous obstacles in the vicinity of the vehicle V and issue an audible or visual warning when such obstacles are in the near vicinity of the vehicle V. Thus, known obstacles (such as mountains or towers) can be simultaneously displayed with obstacles which arise during vehicle V travel (such as, for example, an approaching thunderstorm) and an appropriate audible or visual warning command can be issued. As those of skill in the art will now realize, each obstacle (whether known or which arises during the operation of the vehicle V) can now be continuously displayed in the context of a vehicle's current environment. Because the present invention allows continuous display of a vehicle's environment, obstacles or like threats to the vehicle V can now be displayed much earlier than prior art navigational devices, thereby allowing the vehicle's operator to take appropriate action to avoid the threat.

The display device 61 is further programmed to allow the vehicle V operator to control an input device (such as a computer mouse or trackball, for example) coupled to the electronic medium 21 to determine which selected record from the intermediate database 41 is to be displayed on the display device 61. Those of skill in the art will realize that many techniques may exist to display the selected records (such as, for example, by choosing a pull-down menu and selecting the desired record), however, in the preferred embodiment of the present invention, each record is graphically displayed as a selectable icon placed on the perimeter of the display's 61 viewing area.

The present invention provides information to the vehicle's operator which is generated by both onboard or dynamic and up-loaded or static data sources, thereby allowing the operator to select which features are displayed in real time at any given moment. In the preferred embodiment, the present invention provides warnings and cautions of all known hazards based on the vehicle's coordinate position since the position of all known hazards are stored in latitude, longitude and elevation units which are projected to a common graphical coordinate axis, preferably, nautical miles. Moreover, the preferred embodiment allows such features to be displayed in real time as the vehicle V is in motion so that all text may be shown right side up, regardless of the vehicle's heading. Furthermore, the present invention provides a single integrated display unit in communication with the vehicle's navigational system.

Other variations and modifications of the present invention will be apparent to those of ordinary skill in the art, and it is the intent of the appended claims that such variations and modifications be covered. The particular values and configurations discussed above can be varied, are cited to illustrate particular embodiments of the present invention and are not intended to limit the scope of the invention. It is contemplated that the use of the present invention can involve components having different characteristics as long as the principle, the presentation of a method and apparatus for displaying real time navigational information, is followed.

What is claimed is:

1. On a vehicle having a navigational system and an electronic medium attached to the navigational system, a method for displaying navigational information on a display unit within the vehicle, the method comprising the steps of:

a) creating at least one informational database by a software means, each informational database loaded and stored on the electronic medium;

b) generating at least one intermediate database by the software means, each intermediate database containing projection data representing navigational information, the intermediate database and the software means both being loaded and stored on the electronic medium;

c) allowing the software means to transmit selected portions of the intermediate database to the display unit; and

d) allowing the software means to continuously display and render the selected portions of the intermediate database on the display unit.

2. The method of claim 1 wherein the projection data is created by fusing preselected data from each informational database and projecting the fused preselected data to a common graphical coordinate axis, the axis based on a desired reference point.

3. The method of claim 2 wherein the informational database is selected from the group consisting of environmental terrain data, obstacle data, adjacent vehicle data, special use airspace data, political boundary data, civic boundary data, geographic feature data, navigation aid data, airport information data, airway and intersection data, weather data, cultural data, man-made object data, air traffic data, wind data and flight plan data.

4. The method of claim 3 wherein the electronic medium is a computer means including a control input device.

5. The method of claim 4 wherein the step of generating an informational database further comprises the step of obtaining preselected static information and preselected dynamic information.

6. The method of claim 5 wherein the step of obtaining preselected static information is executed when the vehicle is not operated and the step of obtaining preselected dynamic information is executed when the vehicle is operated.

7. The method of claim 1 wherein the step of generating an intermediate database further comprises the steps of allowing the software means to employ spatial and coordinate culling on the informational database to obtain spatial data stored on the electronic medium, filtering the spatial data by the software means to obtain displayable data corresponding to a geographic vicinity of a desired reference point and projecting the displayable data to a mapping system which contains a common graphical coordinate axis based upon the desired reference point.

8. The method of claim 7 wherein the desired reference point is the vehicle's coordinate position relative to the earth.

9. The method of claim 7 wherein the desired reference point is a preselected geographical coordinate location.

10. The method of claim 8 wherein the step of projecting the displayable data to a mapping system further includes the step of transforming all preselected information containing latitude and longitude information into nautical mile information.

11. The method of claim 10 wherein the step of displaying and rendering the selected portions of the intermediate database on the display unit further comprises the step of displaying text information in a right-side-up view with respect to the vehicle's operator.

12. The method of claim 11 wherein the step of displaying and rendering the selected portions of the intermediate database on the display unit further comprises the step of providing an audible or visual warning when the vehicle is threatened by an obstacle.

13. The method of claim 12 wherein the step of displaying and rendering the selected portions of the intermediate

database on the display unit further comprises the step of displaying at least one desired icon on the display, each icon corresponding to the selected portions of the intermediate database.

14. A method for displaying real time navigational information on a single display device coupled to a vehicle having a navigational system, the method comprising the steps of:

a) providing an electronic medium in communication with the navigational system;

b) creating and storing at least one informational database by a software means stored on the electronic medium;

c) generating and storing an intermediate database on the electronic medium by the software means, the intermediate database containing projection data representing navigational information, the projection data created by fusing preselected data from each informational database and projecting the fused preselected data to a common mapping system containing nautical mile information;

d) transmitting selected portions of the intermediate database to a multicolor display device by the software means; and

e) continuously displaying the selected portions of the intermediate database on the display device.

15. The method of claim 14 wherein the informational database is selected from the group consisting of environmental terrain data, obstacle data, adjacent vehicle data, special use airspace data, political boundary data, civic boundary data, geographic feature data, navigation aid data, airport information data, airway and intersection data, weather data, cultural data, man-made object data, air traffic data, wind data and flight plan data.

16. The method of claim 15 wherein the step of generating an informational database further comprises the step of obtaining preselected static information and preselected dynamic information, the step of obtaining preselected static information being executed when the vehicle is not operated and the step of obtaining preselected dynamic information being executed when the vehicle is operated.

17. An apparatus for displaying a vehicle's coordinate location on a display unit within a vehicle, the vehicle having a navigational system, the apparatus comprising:

a) an electronic medium in communication with the navigational system;

b) an informational database loaded and stored on the electronic medium, the informational database created by a software means stored on the electronic medium;

c) an intermediate database created from the informational database by the software means, the intermediate database being loaded and stored on the electronic medium, the intermediate database containing projection data representing navigational information, the projection data created by fusing preselected data from the informational database and projecting the fused preselected data to a common graphical coordinate axis, the axis based on a desired reference point; and

d) a display device in communication with the electronic medium, the display device receiving selected portions of the projection data and simultaneously and continuously displaying and rendering the selected portions of the projection data.

18. The apparatus of claim 17 wherein the informational database is selected from the group consisting of environmental terrain data, obstacle data, adjacent vehicle data, special use airspace data, political boundary data, civic boundary data, geographic feature data, navigation aid data, airport information data, airway and intersection data, weather data, cultural data, man-made object data, air traffic data, wind data and flight plan data.

19. The apparatus of claim 18 wherein the electronic medium is a computer means including a control input device.

20. The apparatus of claim 19 wherein the informational database contains preselected static information and preselected dynamic information.

21. The method of claim 20 wherein the preselected static information is obtained when the vehicle is not operated and the preselected dynamic information is obtained when the vehicle is operated.

22. The apparatus of claim 21 wherein the desired reference point is the vehicle's coordinate position relative to the earth.

23. The apparatus of claim 22 wherein the desired reference point is a geographical coordinate location.

24. The apparatus of claim 23 wherein the projection data contains nautical mile information.

25. The apparatus of claim 24 wherein the display device displays at least one icon, each icon corresponding to the selected portions of the projection data.

26. An apparatus for displaying a vehicle's coordinate location on a display unit within a vehicle having a navigational system, comprising:

a) and an electronic medium attached to the navigational system;

b) a software means loaded and stored on the electronic medium;

c) at least one informational database created by a software means, each informational database loaded and stored on the electronic medium, each intermediate database created by spatially and coordinately culling the informational database to obtain spatial data stored on the electronic medium, filtering the spatial data by the software means to obtain displayable data corresponding to a geographic vicinity of a desired reference point and projecting the displayable data to a mapping system which contains a common graphical coordinate axis based upon the desired reference point;

d) allowing the software means to transmit selected portions of the displayable data to the display unit; and

e) allowing the software means to continuously display and render the selected portions of the displayable data on the display unit.

* * * * *

Exhibit D

US006664945B1

(12) **United States Patent**
Gyde et al.

(10) **Patent No.:** **US 6,664,945 B1**
(45) **Date of Patent:** **Dec. 16, 2003**

(54) **SYSTEM AND METHOD FOR CONTROLLING COMMUNICATION AND NAVIGATIONAL DEVICES**

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(73) Assignee: **Honeywell International Inc.**, Morristown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 387 days.

(21) Appl. No.: **09/680,582**

(22) Filed: **Oct. 6, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/233,825, filed on Sep. 19, 2000.

(51) **Int. Cl.**[7] **G09G 5/00**

(52) **U.S. Cl.** **345/156**; 340/945; 340/995; 701/14

(58) **Field of Search** 345/156–157, 345/763–764, 829–830; 701/14, 11; 340/990, 995, 945, 971, 973; 455/431

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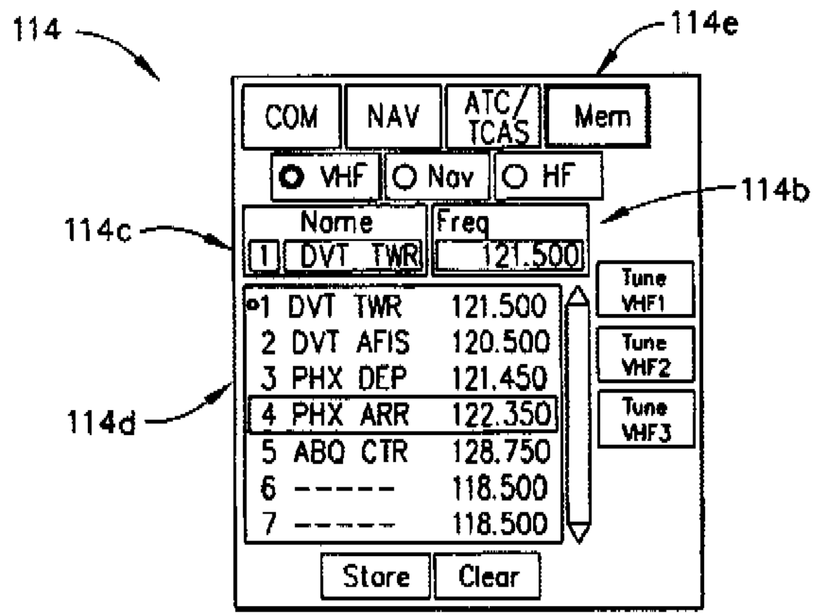
Primary Examiner—Richard Hjerpe
Assistant Examiner—Francis Nguyen

(57) **ABSTRACT**

A system and method for graphically controlling a communication device and displaying its characteristics on a display within a vehicle including a microprocessor, a communication and navigation information window within a portion of the display, the window being generated by and in communication with the microprocessor, at least one radio in communication with and controlled by the microprocessor, a data input means in communication with the microprocessor and at least one communication and navigation information database in communication with the microprocessor. An aircraft operator provides input to a cursor control device and receives visual feedback via a display produced by a monitor. The display includes various graphical elements associated with each radio's characteristics. Through the use of the cursor control device, the operator may modify the radio's characteristics and/or other such indicia graphically in accordance with feedback provided by the display.

21 Claims, 2 Drawing Sheets



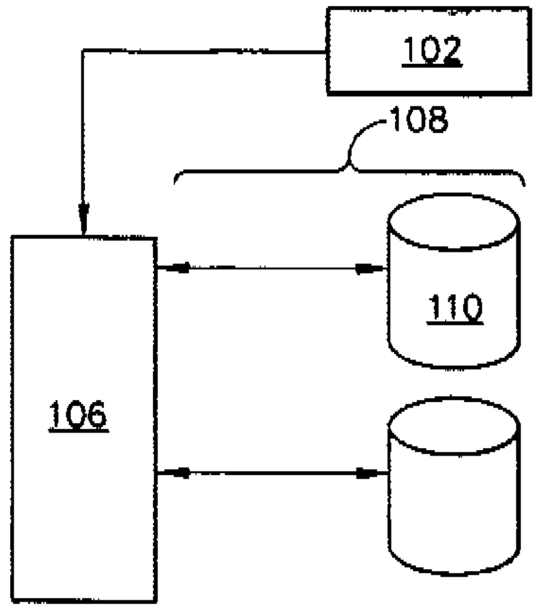


FIG. 1
(PRIOR ART)

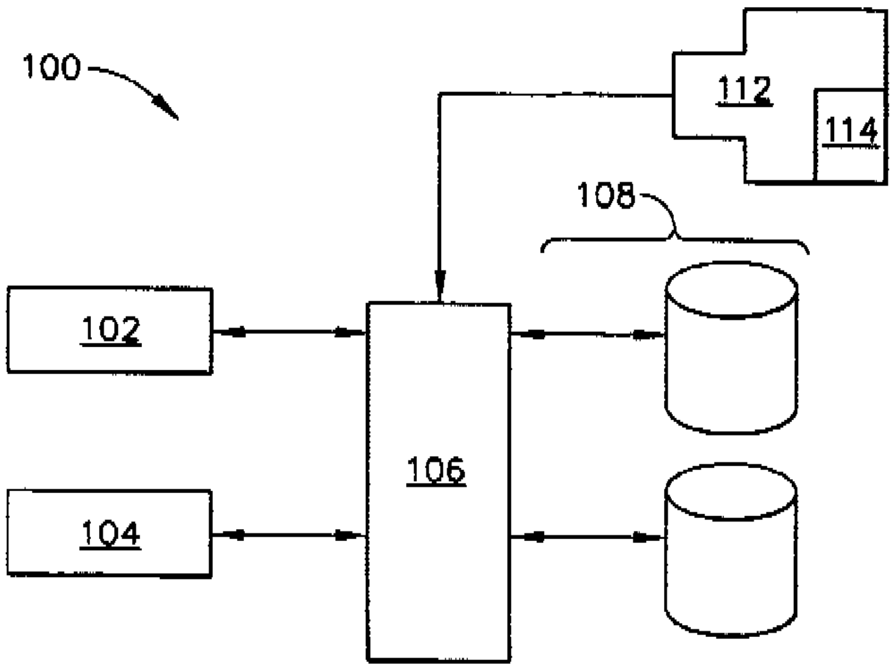
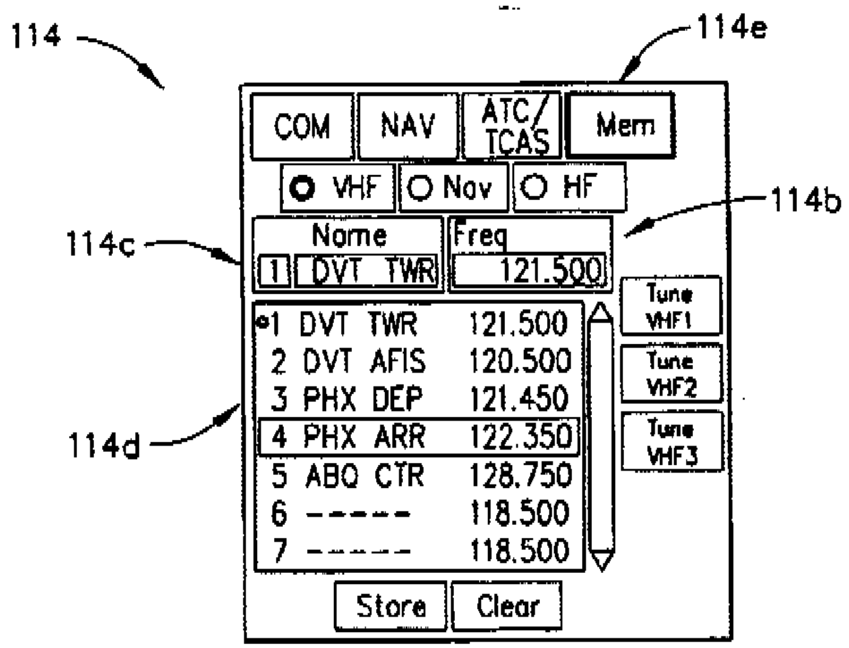


FIG. 2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NAV
ATC/TCAS
Mem
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114c
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Tune VHF3
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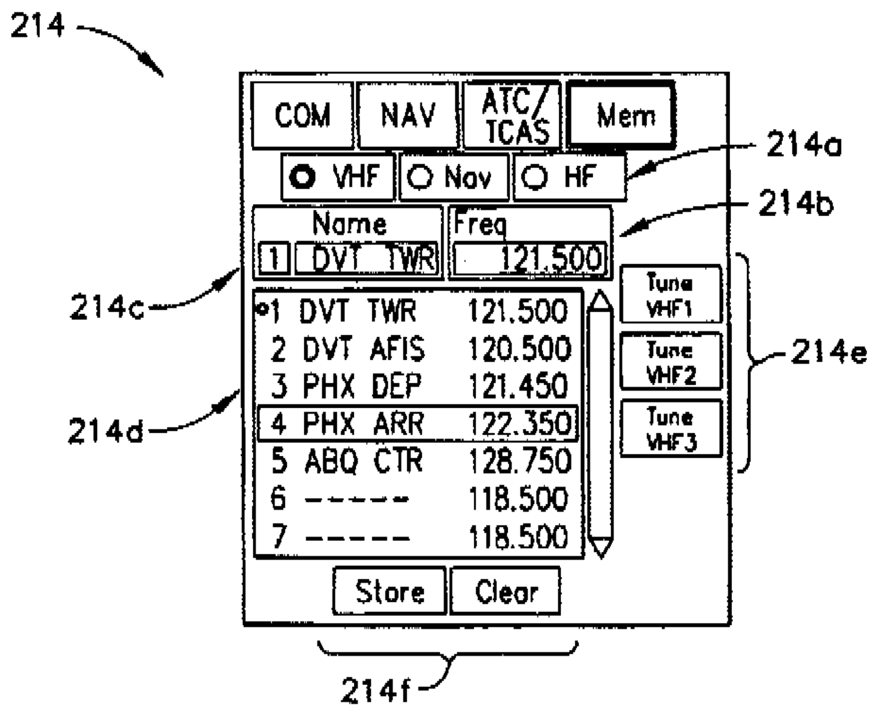
114d
Store
Clear

FIG. 3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2 DVT AFIS 120.500
3 PHX DEP 121.450
4 PHX ARR 122.350
5 ABQ CTR 128.750
6 ----- 118.500
7 ----- 118.500
214d
Store
Clear
214f

FIG. 4

SYSTEM AND METHOD FOR CONTROLLING COMMUNICATION AND NAVIGATIONAL DEVICES

REFERENCE TO RELATED APPLICATION

This application claims priority from and the benefit of U.S. Provisional Patent Application Ser. No. 60/233,825, filed Sep. 19, 2000, the entire contents of which are hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates generally to communication and navigational devices, and more particularly to the control and display of communication and navigational devices within an avionics system.

BACKGROUND OF THE INVENTION

A pilot's awareness and coordination of various aircraft modes and conditions is often critical to optimum aircraft performance and safety. For example, the pilot requires awareness of the aircraft's automation state to easily coordinate the flight modes. Moreover, the pilot should be able to easily view and coordinate the tracking of the aircraft to current modes and targets. The pilot and co-pilot should also be able to easily control all communication and navigational radios on the aircraft regardless of the flight mode However, existing cockpit controls, which may be of the panel-mounted variety or of the head up display (HUD) variety and which may be commonly found in commercial, military, and civilian aircraft, include various systems distributed throughout the cockpit, thereby often requiring the pilot to intermittently scan various areas of the cockpit to obtain and analyze the aircraft information. Moreover, various communication controls may be spaced throughout the cockpit, which may require the pilot and the co-pilot to reach into each other's immediate space in order to modify or select the controls. The current arrangement of such controls throughout the cockpit does not allow the pilots to fly the aircraft as efficiently as possible.

To assist the pilot, aircraft flight displays continue advancing, achieving increasingly higher levels of information density and, consequently, presenting a greater amount of visual information for the operator. In many applications, it is often important that visual displays provide a proper cognitive mapping between what the operator is trying to achieve and the information available to accomplish the task. As a result, such systems increasingly utilize human-factor design principles in order to build instrumentation and controls that work cooperatively with human operators.

Accordingly, the Federal Aviation Administration (FAA) has promulgated a number of standards and advisory circulars relating to flight instrumentation. More particularly, Title 14 of the U.S. Code of Federal Regulations, Federal Aviation Regulations (FAR) Part 25, Sec. 25.1321 et seq. provides guidelines for arrangement and visibility of instruments, warning lights, annunciators, and the like. Similarly, detailed guidelines related to electronic displays can be found in FAA Advisory Circular 20-88A, *Guidelines on the Marking of Aircraft Powerplant Instruments* (Sep. 1985), both of which are incorporated by reference.

Typical communication and navigation radios used today are manually intensive to control. For example, a typical communication radio within an aircraft includes a plurality of buttons, flip switches and/or rotatable tuning knobs. The rotatable tuning knobs control the particular frequency the

radio is transmitting and receiving. If the vehicle's operator desired to change the frequency, the tuning knobs must be rotated. If the frequency shift is large, the operator is required to continually rotate the knobs until the desired frequency is achieved. This can be a cumbersome chore. This problem is exacerbated when there are multiple communication radios and navigation radios throughout the cockpit. Communication and navigation radios are typically located in the upper portion of the flight deck outside of the pilot's primary scanning view but within arms reach. The placement of these radios further takes the pilot's attention away from his primary duty to operate the aircraft. Consequently, the reaction time associated with adjusting the characteristics of each radio throughout the cockpit may potentially affect the safe operation of the vehicle.

What is needed is a system for controlling and displaying communication devices and navigational devices, and storing information relating to such devices in an easy and efficient manner which allows the vehicle's operator to concentrate on the primary task of operating the vehicle.

BRIEF SUMMARY OF THE INVENTION

The present invention is, in one embodiment, a system and method for graphically controlling a communication device and displaying its characteristics on a display within a vehicle including a microprocessor, a communication and navigation information window within a portion of the display, the window being generated by and in communication with the microprocessor, at least one radio in communication with and controlled by the microprocessor, a data input means in communication with the microprocessor and at least one communication and navigation information database in communication with the microprocessor. An aircraft operator provides input to a cursor control device and receives visual feedback via a display produced by a monitor. The display includes various graphical elements associated with each radio's characteristics. Through the use of the cursor control device, the operator may modify the radio's characteristics and/or other such indicia graphically in accordance with feedback provided by the display.

The novel features of the present invention will become apparent to those of skill in the art upon examination of the following detailed description of the invention or can be learned by practice of the present invention. It should be understood, however, that the detailed description of the invention and the specific examples presented, while indicating certain embodiments of the present invention, are provided for illustration purposes only because various changes and modifications within the spirit and scope of the invention will become apparent to those of skill in the art from the detailed description of the invention and claims that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying figure further illustrates the present invention and, together with the detailed description of the invention, serve to explain the principles of the present invention.

FIG. 1 shows an exemplary prior art primary flight display with a separate radio management unit;

FIG. 2 illustrates a block diagram schematic of one embodiment of the present invention; and

FIG. 3 shows an flight display including a radio management system according to the present invention; and

FIG. 4 shows an flight display including a radio management system according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention may be described herein in terms of functional block components and various processing steps known to those of skill in the art. Such functional blocks may be realized by any number of hardware, firmware, and/or software components configured to perform the specified functions. For example, the present invention may employ various integrated circuit components, e.g., memory elements, digital signal processing elements, look-up tables, and the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices. Moreover, it should be understood that the exemplary process illustrated may include more or less steps or may be performed in the context of a larger processing scheme. Furthermore, the various flowcharts or methods presented in the drawing figures or the specification are not to be construed as limiting the order in which the individual process steps may be performed.

FIG. 1 illustrates an exemplary radio communications system within a vehicle of the prior art. In this type of system, a processor **106** is configured to communicate with one or more data sources **108** and at least one communication or navigation radio **102**. The controls for radio **102** are typically placed adjacent to the operator's line of sight on the primary vehicle control panel, but as explained previously, such controls may be arranged throughout the operator's environment. In general, a user (e.g., a pilot) located within a vehicle (e.g., aircraft, which is not shown) may provide input to processor **106** via a front control panel of the radio **102**. As stated previously, the location of each radio **102** throughout the vehicle made it difficult for the vehicle operator to focus on operating the vehicle.

FIG. 2 illustrates one embodiment of the present invention. In this embodiment, the present invention is a system **100** for graphically controlling a communication device's **102** characteristics on a portion **114** within a display **112** comprising a processor **106** configured to communicate with at least one monitor **112**, one or more data sources **108** and a data input means **104**. In general, a user (e.g., a pilot) located within a vehicle (e.g., aircraft, which is not shown) may provide input to processor **106** via an input device **104** and receive visual feedback regarding the status of the vehicle's communication and navigation devices **102** via a communication information window **114** produced by monitor **112**. FIG. 3 illustrates one embodiment of the present invention as may be seen by the vehicle's operator on a display **112**. Those of skill in the art will realize that system **100** may be suitably configured for use any vehicle which has a communication system.

According to one aspect of the present invention as seen in FIG. 2, the system for graphically controlling a communication device **102** on a display **112** generally includes a microprocessor **106**, an information window **114** within a portion of the display **112** (as seen in FIG. 3, for example), at least one radio communication device **102** a data input means **104** and at least one information database **108**, all in communication with the microprocessor **106**. In one preferred embodiment, the information window **114** is generated by and in communication with the microprocessor **106**, while each communication database **108** contains radio and communication information (such as pre-stored lookup tables corresponding to certain geographical locations and their respective communication frequencies). Preferably, each radio communication device can be selected from very high frequency communication radios, high frequency communication radios and navigation radios.

Moreover, as seen in FIG. 3, the information window may further preferably include a frequency tuning portion **114***b*, an alphanumeric text portion **114***c* adjacent to the tuning portion **114***b*, a scrollable stored frequency portion **114***a* adjacent to the text portion and the tuning portion and at least one selectable tab **114***e* adjacent to the tuning portion **114***b* and the text portion **114***c*, all in communication with the microprocessor **106**.

Preferably, the data input means **104** is a cursor control means having a cursor or like graphical symbol graphically and dynamically displayed within the window **114**, or more particularly, an alphanumeric keyboard and mouse-like device. The cursor displayed within the window **114** may further change shape in the window **114** in response to data entered into the data input means **104**. The data input means **104** may further include a multi-function keyboard with a viewable text entry portion (not shown), the text entry portion displaying text entered into the cursor control means by the operator which assists the operator in entering alphanumeric text.

The alphanumeric text portion **114***c* may be configured to allow data input corresponding to a predefined identifier (such as, for example, a geographic location such as "PHX" representing the City of Phoenix). Similarly, the frequency tuning portion **114***b* may be configured to allow data input corresponding to a predefined frequency so that the predefined frequency corresponds to the predefined identifier (e.g., the frequency 100.30 may correspond to a communication frequency for the City of Phoenix). As a means for quickly locating previously stored identifiers and frequencies, the stored frequency portion **114***a* is employed within window **114** to display at least one predefined identifier and a corresponding predefined frequency. It is a common practice in the operation of commercial vehicles to use multiple operators (such as pilots, for example) throughout the day, each operator potentially operating the same vehicle in different geographic locations (e.g., one pilot flying from Phoenix to Albuquerque, another pilot flying from Albuquerque to Las Vegas). As such, as those of skill in the art will now appreciate, communication frequencies and navigational frequencies can be stored and displayed by the stored frequency portion **114***a* whether during operation of the vehicle or otherwise, thereby giving a vehicle's various operators the ability to modify or retain desired frequencies. Further, the present invention minimizes the amount of physical work required by a vehicle operator to set or store such frequencies by allowing direct text entry corresponding to such frequencies and/or geographical locations.

System **100** is preferably configured such that display element **112** produces an enhanced rendering of various aspects of a communication system **100** and the communication system's characteristics (as illustrated, for example, in FIG. 3) as viewed by the operator of the vehicle. A number of aspects of display element **112** (which are controlled by processor **106** in a practical embodiment) may contribute to the improved contents and appearance of the information window **114**. The image generation and display aspects of the present invention may leverage known techniques such that existing communication systems can be modified in a straightforward manner to support the different features described herein. In a practical implementation, the concepts of the present invention may be realized in the form of revised display generation software or processing resident at processor **106**.

Processor **106** encompasses one or more functional blocks used to provide flight management and control, control the on-board communication system, interface with the pilot, and input to monitor 112. Processor 106 may include or cooperate with any of the on-board radios within the communication system, such as high frequency communication radios, very high frequency radios and navigation radios. In addition, processor 106 may be configured to receive, analyze, condition, and process information received from the communication system. In this regard, processor 106 may include any number of individual microprocessors, flight computers, navigation equipment, memories, storage devices, interface cards, and other technologies known in the art. Moreover, processor 106 may include any number of microprocessor elements, memory elements, power supplies, and other functional components as necessary. In this respect, processor 106 may include or cooperate with any number of software programs or instructions designed to carry out various methods, process tasks, calculations, control functions, and the generation of display signals and other data used by display element 112 and the control and transfer of data between the communication system 100 and the display 112.

Display 112 may also include various graphical elements associated with the lateral position, vertical position, flight-plan and/or other indicia of the aircraft's operational state as determined from data sources 108. Display 112 may also be based on a panel mounted display, a HUD projection, or any known technology. Display 112 may include any number of conventional elements, e.g., visual indicators, alphanumeric text, lights, and the like.

In another embodiment, the present invention is implemented with a large 14.1" diagonal display to provide much more display surface area in front of the pilot. As such, the present invention is configured to allow the enlargement and enhancement of the annunciation areas while substantially maintaining the surface area allotted for other displays. Alternatively, the present invention is implemented within an 8Δ×10" display or any other suitable display size.

Data 108 may include standard information related to the state of the vehicle. Data sources 108 include various types of data required by the system, for example, flight plan data, data related to airways, navigational aids (Navaids), symbol textures, navigational data, obstructions, font textures, taxi registration, Special Use Airspace, political boundaries, communication frequencies (enroute and airports), approach information, and the like.

In another embodiment as seen in FIG. 4, the present invention is a display system having a communication window 214 therein. In this embodiment, as illustrated in FIG. 4, the window contains at least one radio select means 214*a*, a selectable alphanumeric text portion 214*c*, a selectable frequency tuning portion 214*b*, a scrollable frequency list having a plurality of location and frequency records 214*d* and a plurality of radio tuning buttons 214*e*. Each of the radio select means 214*a*, the selectable alphanumeric text portion 214*c*, the selectable frequency tuning portion 214*b*, the scrollable frequency list 214*d* and the plurality of radio tuning buttons 214*e* in communication with and being controlled by a microprocessor 206 (not shown, but similar in disclosure to the operation of microprocessor 106).

The radio select means 214*a* correspond to memory locations for a particular radio (e.g., communication radio, navigational radio, high frequency radio, etc.) having stored geographical and frequency information. An operator would use radio select means 214*a* to select a particular radio 102 to control. The alphanumeric text portion 214*c* and the frequency tuning portion 214*b* are used to enter, clear or otherwise modify an item from any record within the frequency list 214*d*. The frequency list 214*d* identifies at least one predefined identifier record and a corresponding predefined frequency record. When either record is selected from the frequency list 214*d*, its contents are transferred to the text portion 214*c* and the frequency portion 214*b* where such contents can be modified by the operator via input device 204 (not shown). The storage select means 214*f* is employed by the operator to store or clear a record within the frequency list 214*d*. The storage select means 214*f* is configured only to store or clear those records displayed in the text portion 214*c* and the frequency tuning portion 214*b*.

In operation, the vehicle's operator may first select a radio tuner 214*a* within the information window 214 (e.g., "VHF") by the data input means 204. The operator can then select a record from the frequency list 214*d*, which displays the previously stored text and frequency information within the text portion 214*c* and the frequency portion 214*b*. The operator can then, though the data input means 204, enter a new frequency or text identifier as desired, select the storage select means 214*f* and store the new text or frequency in database 108. Those of skill in the art will appreciate that similar steps are taken to clear certain text or frequency records displayed in the frequency list 214*d*.

In the illustrated embodiment, certain visual cues are used to signal to the aircraft operator that the radio memory management system is activated. For example, the shape of the cursor may change or provide a particular characteristic to alert the operator that the radio memory management system is activated. Further, any alphanumeric field within the radio memory management system portion 214 of the display is preferably programmed to prevent unauthorized entry of invalid data (such as, for example, an invalid frequency) or to prevent entry of data in an unselected field. When the alphanumeric text entered within a field is acceptable, the user will accept the entry by appropriately selecting the CCD. The respective radio will then change its settings based upon the alphanumeric entry provided by the operator.

It should further be appreciated that the particular implementations shown and described herein are illustrative of the various embodiments of the invention and its best mode, and are not intended to otherwise limit the scope of the present invention in any way. For the sake of brevity, conventional techniques and components related to aircraft attitude detection, flight instrumentation, liquid crystal displays, HUDs, image rendering, landing and guidance methodologies, and other functional aspects of the systems (and components of the individual operating components of the systems) known to those of skill in the art may not be described in detail herein. Furthermore, the display images illustrated are exemplary in nature and are not intended to limit the scope or applicability of the present invention in any way.

Other variations and modifications of the present invention will be apparent to those of ordinary skill in the art, and it is the intent of the appended claims that such variations and modifications be covered. The particular values and configurations discussed above can be varied, are cited to illustrate particular embodiments of the present invention and are not intended to limit the scope of the invention. It is contemplated that the use of the present invention can involve components having different characteristics as long as the principle, the presentation of a system for controlling communication devices and navigational devices, is followed.

The embodiments of an invention in which an exclusive property or right is claimed are defined as follows:

1. A vehicle display containing a communication information window, the window comprising:

a. at least one radio select means;

b. a selectable alphanumeric text portion;

c. a selectable frequency tuning portion;

d. a scrollable frequency list having a plurality of location and frequency records;

e. at least one radio tuning button; and

f. a storage select means in communication with the frequency list; the radio select means, text portion, tuning portion, frequency list, tuning buttons and storage select means each in communication with a microprocessor, the microprocessor in communication with at least one radio means, and each radio tuning button corresponding to each radio means.

2. The system of claim 1, the text portion being configured to allow data input corresponding to a predefined identifier.

3. The system of claim 2, the tuning portion being configured to allow data input corresponding to a predefined frequency, the predefined frequency corresponding to the predefined identifier.

4. The system of claim 3, the frequency list being configured to display at least one predefined identifier and a corresponding predefined frequency.

5. The system of claim 4, each radio tuning button being configured to display tuning characteristics of the radio select means selected, each button further allowing the characteristics to be changed in the text portion or the frequency tuning portion.

6. The system of claim 5, the storage select means allowing the entry or deletion of the predefined frequency or the predefined identifier.

7. The system of claim 6, each radio select means selected from the group consisting of very high frequency communication radios, high frequency communication radios and navigation radios.

8. A system for graphically controlling an aircraft communication device on a on of a display within aircraft, the system comprising:

a. at least one radio tuner within the portion;

b. a selectable alphanumeric text portion within the portion;

c. a selectable frequency tuning portion within the portion;

d. a scrollable frequency list within the portion, the frequency list having a plurality of location and frequency records;

e. a storage select means within the portion, the storage select means in communication with the frequency list;

f. at least one radio in communication with each radio tuner,

g. a controllable cursor control device, the device accepting input from an operator; and

h. a processor coupled to the cursor control device and the display portion, the processor processing input from the user to produce an image on the display portion viewable by the operator, the display portion further including a cursor symbol responsive to input from the cursor control device.

9. The system of claim 8, the text portion being configured to allow data input corresponding to a predefined identifier.

10. The system of claim 9, the tuning portion being configured to allow data input corresponding to a predefined frequency, the predefined frequency corresponding to the predefined identifier.

11. The system of claim 10, the frequency list being configured to display at least one predefined identifier and a corresponding predefined frequency.

12. The system of claim 11, each radio tuner being configured to display tuning characteristics of the radio select means selected, each tuner further allowing the characteristics to be changed in the text portion or the frequency tuning portion.

13. The system of claim 12, the storage select means allowing the entry or deletion of the predefined frequency or the predefined identifier.

14. The system of claim 13, each radio select means selected from the group consisting of very high frequency communication radios, high frequency communication radios and navigation radios.

15. A method for displaying communication information within a portion of a display on a vehicle, the method comprising:

a. providing a window within the display;

b. providing at least one radio select means within the window;

c. providing a selectable alphanumeric text portion within the window;

d. providing a selectable frequency tuning portion within the window;

e. providing a scrollable frequency list within the window, the frequency list having a plurality of location and frequency records;

f. providing at least one radio tuning button within the window; and

g. providing a storage select means within the window, the storage select means in communication with the frequency list; the display, radio select means, text portion, tuning portion, frequency list, tuning buttons and storage select means each in communication with a microprocessor, the microprocessor in communication with at least one radio means, each radio tuning button corresponding to each radio means.

16. The method of claim 15, the text portion being configured to allow data input corresponding to a predefined identifier.

17. The method of claim 16, the tuning portion being configured to allow data input corresponding to a predefined frequency, the predefined frequency corresponding to the predefined identifier.

18. The method of claim 17, the frequency list being configured to display at least one predefined identifier and a corresponding predefined frequency.

19. The method of claim 18, each radio tuning button being configured to display tuning characteristics of the radio select means selected, each button further allowing the characteristics to be changed in the text portion or the frequency tuning portion.

20. The method of claim 19, the storage select means allowing the entry or deletion of the predefined frequency or the predefined identifier.

21. The method of claim 20, each radio select means selected from the group consisting of very high frequency communication radios, high frequency communication radios and navigation radios.

* * * * *

Exhibit E

US006691030B2

(12) United States Patent
Winikka

(10) **Patent No.:** **US 6,691,030 B2**
(45) **Date of Patent:** **Feb. 10, 2004**

(54) **SYSTEM AND METHOD FOR LOCATING A WAYPOINT**

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(73) Assignee: **Honeywell International Inc.**, Morristown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **G01C 21/00**
(52) **U.S. Cl.** **701/206**; 701/213
(58) **Field of Search** 701/3, 14, 200, 701/206, 207, 213; 342/357.01; 340/945

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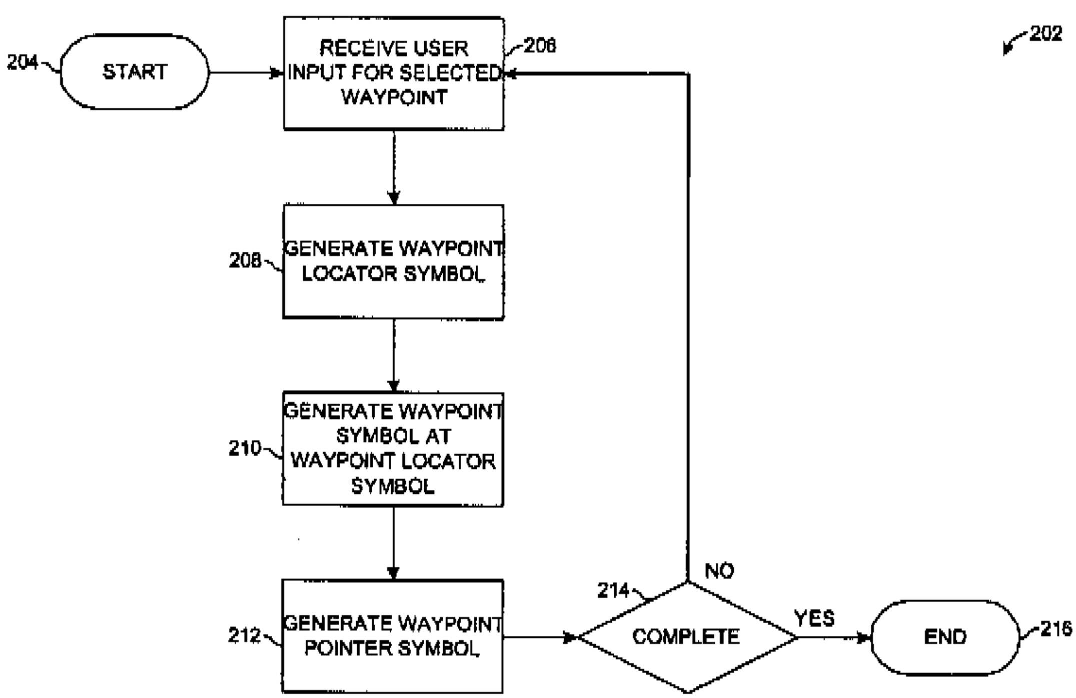
Primary Examiner—Yonel Beaulieu

(57) **ABSTRACT**

A navigation system may be used to generate a navigation map for a flight display for an aircraft. The navigation map may include waypoint symbols representing various waypoints, landmark symbols representing various landmarks, and/or navigation data symbols representing various navigation data. Upon receiving a user input selecting a waypoint, the navigation system generates a waypoint locator symbol for the corresponding selected waypoint and generates a waypoint pointer symbol between the waypoint locator symbol and a position on the navigation map representing a present position. In some instances, the navigation system generates a selected waypoint symbol within the waypoint locator symbol.

25 Claims, 5 Drawing Sheets



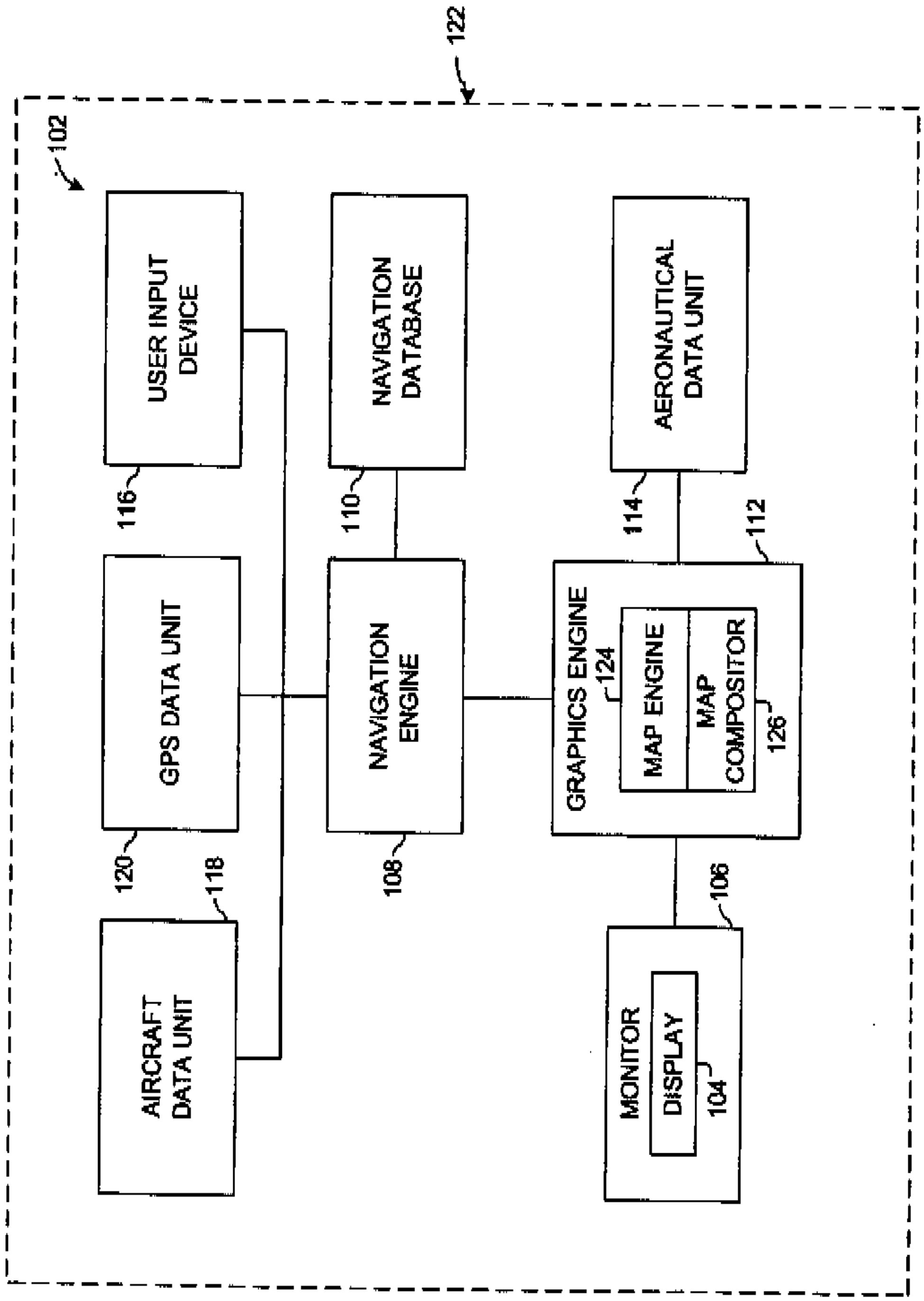

122
102
USER INPUT DEVICE
116
NAVIGATION DATABASE
110
AERONAUTICAL DATA UNIT
114
GPS DATA UNIT
120
NAVIGATION ENGINE
108
GRAPHICS ENGINE
112
MAP ENGINE
124
MAP COMPOSITOR
126
AIRCRAFT DATA UNIT
118
MONITOR
DISPLAY
104
106

FIG. 1