[redacted]

From: Mcnutt, Jan (HQ-MC000)
Sent: Thursday, April 16, 2009 11:48 AM
To: Robert Adams-OTG
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.
Attachments: Optima Claim Response Letter.pdf

Dr. Adams,

Please refer to the attached document.

Please respond to this email that you have received the attached document.

Regards,

Jan S. McNutt
Senior Attorney (Commercial)
Office of the General Counsel
NASA Headquarters
[redacted]

From: Robert Adams-OTG [redacted]
Sent: Thursday, April 16, 2009 11:05 AM
To: Mcnutt, Jan (HQ-MC000)
Subject: FW: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

16APR09

Jan,

Can you please provide me an update as to this matter?

Dr. Adams

From: Robert Adams-OTG [redacted]
Sent: Tuesday, March 10, 2009 8:11 AM
To: 'McNutt, Jan (HQ-MC000)'
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

10MAR09

Jan,

01140

Can you please provide me an update as to this matter?

Dr. Adams

From: McNutt, Jan (HQ-MC000) [redacted]
Sent: Friday, February 20, 2009 2:07 PM
To: Robert Adams-OTG
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Dr. Adams,

Thank you for your email concerning the new licensees and thank you for your patience. We are awaiting for one final communication from one of our sources that will allow us to come to a final decision and that source has indicated they are working to get us an answer by next week.

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Jan S. McNutt
Senior Attorney (Commercial)
[redacted]

From: Robert Adams-OTG [redacted]
Sent: Thursday, February 12, 2009 5:35 PM
To: McNutt, Jan (HQ-MC000)
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

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We have now licensed Cobham the parent company of Chelton Flight System and expect to wrap up a license for Rockwell in the coming weeks.

Attached you will find the voicemail from Cobham's attorney that concluded a yearlong drawn out process; as I write this letter we await the signed hard copies in the mail.

We shall be filing in Federal Court against Garmin in the coming months as they are the last one who is being definite due to their bad advice from a money hungry attorney.

Can you please provide me a status as to the resolve regarding the issues between our two companies'?

With the recent new licensee's I remain optimistic that this business matter can be resolved peacefully between our two companies.

Thank you,

Robert

From: McNutt, Jan (HQ-MC000) [redacted]
Sent: Thursday, January 22, 2009 1:16 PM
To: Robert Adams-OTG
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Dr. Adams,

[redacted]

Regards, (b)(5)

Jan S. McNutt
Senior Attorney (Commercial)
[redacted]

From: Robert Adams-OTG [redacted] (b)(6)
Sent: Saturday, December 27, 2008 7:27 PM
To: McNutt, Jan (HQ-MC000)
Subject: FW: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Mr. McNutt,

Please advise us as to our progress of settlement on this matter and NASA taking a license of our patented technology.

I will advise you that a lack of response or no response could be a violation of Rule 11, thus your continued delay tactics could allow us to move forward and ask the court to impose an appropriate sanction.

Dr. Adams

From: Robert Adams-OTG [redacted] (b)(6)
Sent: Friday, October 03, 2008 5:18 AM
To: 'McNutt, Jan (HQ-MC000)'
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Mr. McNutt,

Our company provided you're everything that had been requested by your counsel as all of that is legal and current, for you to say otherwise is nothing more than an attempt to delay the process and shall be brought up latter to the judge should this matter go to court.

Dr. Adams

From: McNutt, Jan (HQ-MC000) [redacted] (b)(6)
Sent: Wednesday, October 01, 2008 7:58 AM
To: Robert Adams-OTG
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Dear Mr. Adams,

[redacted]

(b)(4) + (b)(5)

Regards,

01142

Jan S. McNutt
Senior Attorney (Commercial)
Office of the General Counsel
NASA Headquarters
[redacted] (b)(6)

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From: Robert Adams-OTG [redacted] (b)(6)
Sent: Tuesday, September 30, 2008 1:04 PM
To: McNutt, Jan (HQ-MC000)
Subject: FW: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

[redacted]

(b)(4)

From: Robert Adams-OTG [redacted] (b)(6)
Sent: Monday, August 25, 2008 3:48 PM
To: 'McNutt, Jan (HQ-MC000)'; '[redacted]
Subject: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Sent via U.S. Mail with tracking number

Jan S. McNutt,

Please see the attached letter; it is your response to your most recent letter.

Thank you,

Dr. Robert Adams – CEO
Optima Technology Group
[redacted] (b)(6)

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National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

March 19, 2009

Reply to Attn of: Office of the General Counsel

CERTIFIED MAIL

Dr. Robert Adams, CEO
Optima Technology Group
[redacted] (b)(6)

RE: Administrative Claim for Infringement of US Patent No. 5,904,724; NASA Case No. I-222

Dear Dr. Adams:

This letter concerns the above-identified administrative claim for patent infringement.

NASA received the initial notification of this claim in an email dated May 12, 2003, from Mr. Jed Margolin addressed to attorneys at the NASA Langley Research Center claiming that "NASA may have used one or more of [Mr. Margolin's] patents in connection with the X-38 project and may be using one or more of my patents in other projects using Synthetic Vision". Mr. Margolin identified two patents that he believed NASA may be infringing; the subject patent and Patent No. 5,566,073. On June 7, 2003, Mr. Margolin submitted his claim by fax to the NASA HQ attorney, Mr. Alan Kennedy. Mr. Kennedy responded by letter dated June 11, 2003 acknowledging the administrative claim and requesting that Mr. Margolin give a more detailed breakdown of the exact articles or processes that constitute the claim. Mr. Margolin responded by letter dated June 17, 2003, withdrawing his claim with regard to U.S. Patent No. 5,566,073, leaving the remaining claim for the subject patent. NASA is aware of the long pendency of this matter and we regret the delay.

On July 14, 2008 Optima Technology Group sent a letter addressed to Mr. Kennedy stating that they were the owners of the Jed Margolin patents due to an assignment and requesting that NASA now license the technology of the subject patent. With an email dated August 6, 2008 from Optima, NASA received a copy of a Patent Assignment, dated July 20, 2004, executed by Jed Margolin, the sole inventor on the subject patent, by which the entire right, title and interest in the patent has been assigned to Optima Technology Group, Inc. We previously noted in a letter dated August 20, 2008 from Mr. Jan McNutt of our office addressed to you that NASA believes there are certain irregularities surrounding this and collateral assignment documents associated with the subject patent. However, NASA will at this time forestall a detailed consideration of that issue. Instead, we will assume your *bona fides* in asserting that you are the legitimate owner of the subject patent and communicate our findings directly with you. To the extent that Mr. Margolin has any interest in this matter, formally or informally, we will leave it up to you whether or not to communicate with him.

In light of the prior claim by Mr. Margolin, we consider your license proffer as an administrative claim of patent infringement. We turn now to the substance of your claim. In response to your initial letter dated July 14, 2008, Mr. McNutt's August 20, 2008 letter posed a number of questions, the purpose of which was to enable NASA to fully evaluate the details of your claim. Your organization failed to respond to these questions and, further, advanced the position that this matter does not involve a *new* claim (*Adams letter to McNutt, August 25, 2008*). We disagree that this is not a new claim. Nevertheless, NASA proceeds – in order to bring closure to this matter – on the basis that this claim centers around allegations that infringement arose from activities associated with NASA's X-38 Program, as advanced by Mr. Margolin. Accordingly, our investigation of this claim necessarily reflects the answers previously furnished by Mr. Margolin in response to NASA's June 11, 2003 letter to him containing substantially the same set of questions.

U.S. Patent No. 5,904,724 issued with twenty claims, claims 1 and 13 being the sole independent claims.

In order for an accused device to be found infringing, each and every limitation of the claim must be met by the accused device. To support a finding of literal infringement, each limitation of the claim must be met by the accused device exactly, any deviation from the claim precluding a finding of infringement. See *Lantech, Inc. v. Keip Mach. Co.*, 32 F.3d 542 (Fed. Cir. 1994). If an express claim limitation is absent from an accused product, there can be no literal infringement as a matter of law. See *Wolverine World Wide, Inc. v. Nike, Inc.*, 38 F.3d 1192, 1199 (Fed. Cir.1994).

In applying these legal precepts, reproduced below are the relevant portions of claims 1 and 13.

> Claim 1. A system comprising:
>
> * * *
>
> a computer
>
> * * *
>
> said computer is. . .for ***determining a delay time*** for communicating said flight data between said computer and said remotely piloted aircraft, and wherein said computer adjusts the sensitivity of said set of one or more remote flight controls based on said delay time. (emphasis added.)
>
> Claim 13. A station for flying a remotely piloted aircraft that is real or simulated comprising:
>
> * * *
>
> a computer
>
> * * *

> said computer. . . to *determine a delay time* for communicating. . .flight control information between said computer and [a] remotely piloted aircraft, and said computer to adjust the sensitivity of [a] set of remote flight controls based on said delay time. . . .(emphasis added.)

NASA has investigated activities surrounding the X-38 program at its Centers that conducted X-38 development efforts and has determined that no infringement has occurred. This result is compelled because none of NASA's X-38 implementations utilized a computer which is "for determining a delay time for communicating said flight data between said computer and said remotely piloted aircraft," as required by claim 1, nor a "computer ... to determine a delay time for communicating ... flight control information between said computer and [a] remotely piloted aircraft," as required by the limitations of claim 13.

Given that a computer which measures delay time is lacking from the NASA X-38 configuration, it follows that the NASA X-38 configuration had no "adjusting of the sensitivity of [a] set of one or more remote flight controls based on said delay time", as required in claim 1. Similarly, because the NASA X-38 configuration had no "computer to determine a delay time for communicating ... flight control information between said computer and [a] remotely piloted aircraft, the configuration also had no adjusting of "the sensitivity of [a] set of remote flight controls based on said delay time", as called for by claim 13.

For at least the above-explained exemplary reasons, claims 1 and 13 have not been infringed. It is axiomatic that none of the dependent claims may be found infringed unless the claims from which they depend have been found to be infringed. *Wahpeton Canvas Co. v. Frontier, Inc.*, 870 F.2d 1546 (Fed. Cir. 1989). One who does not infringe an independent claim cannot infringe a claim dependent on, and thus containing all the limitations of, that claim. *Id.* Thus, none of claims 2-12 and 14-20 have been infringed.

NASA's X-38 development efforts ended in 2002. There may also be other features in NASA's X-38 development efforts that, upon further analysis, would reveal yet more recited claim limitations that are lacking in the NASA configuration related to those efforts.

We also note as a point of particular significance that the limitations included in claims 1 and 13 discussed above were added by amendment during the prosecution of the patent application. It is clear from an analysis of the patent application file wrapper history that the individual prosecuting the application stressed the importance of "the measurement of a communication delay in order to adjust the sensitivity of flight controls based on that delay." Also noted is the distinguishing arguments that these claims require that there be a "computer ... located in the pilot station" and that "at least one real time measurement of the delay and some adjustment is contemplated." (See *Applicant's Amendment and Remark*, February 27, 1998 and *Response Under 37 C.F.R. § 1.116*, July 6, 1998). Clearly, the Patent Office Examiner allowed the application based on these prosecutorial arguments.

We have completed our investigation regarding the claim of patent infringement of U.S. Patent No. 5,904,724 and have determined that there is no patent infringement by, or unauthorized use on behalf of, NASA. The above detailed discussion explains the basis for NASA's analysis and decision regarding the subject administrative claim.

As an aside, during NASA's investigation, numerous pieces of evidence were uncovered which would constitute anticipatory prior knowledge and prior art that was never considered by the U.S. Patent and Trademark Office during the prosecution of the application which matured into Patent No. 5,904,724. In view of the clear finding of lack of infringement of this patent, above, NASA has chosen to refrain from a discussion that would demonstrate, in addition to non-infringement, *supra*, invalidity of the subject patent. However, NASA reserves the right to introduce such evidence of invalidity in an appropriate venue, should the same become necessary.

This is a FINAL agency action and constitutes a DENIAL of the subject administrative claim for patent infringement.

Pursuant to 35 U.S.C. § 286, the statute of limitations for the filing of an action of patent infringement in the United States Court of Federal Claims is no longer tolled. Thus, any further appeal of this decision must be made by filing a claim for patent infringement in the United States Court of Federal Claims, pursuant to 28 U.S.C. § 1498(a).

Sincerely,

Gary G. Borda
Agency Counsel for Intellectual Property

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DL. L. ADAMS CEO
OPTIMA TECH GROUP
[redacted]

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(b)(6)

[redacted]

From: Mcnutt, Jan (HQ-MC000)
Sent: Thursday, April 16, 2009 12:36 PM
To: Borda, Gary G. (HQ-MC000); Graham, Courtney B. (HQ-MC000); Rotella, Robert F. (HQ-MC000)
Cc: Bayer, Kathy (HQ-MC000)
Subject: FW: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

[redacted] (b)(5)

From: Robert Adams-OTG [redacted] (b)(6)
Sent: Thursday, April 16, 2009 12:05 PM
To: Mcnutt, Jan (HQ-MC000)
Subject: RE: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

Jan,

As of today we are in receipt of said documents you just sent us and have never received them nor viewed them till today.

Dr. Adams

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[redacted] (b)(5)

[redacted]

[redacted]

Jan S. McNutt
Senior Attorney (Commercial)
Office of the General Counsel
NASA Headquarters
[redacted] (b)(6)

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[redacted]

[redacted]s

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Sent: Monday, August 25, 2008 3:48 PM
To: 'McNutt, Jan (HQ-MC000)'; [redacted]
Subject: Jan S. McNutt, Please see the attached letter; it is your response to your most recent letter.

II

Sent via U.S. Mail with tracking number

Jan S. McNutt,

Please see the attached letter; it is your response to your most recent letter.

Thank you,

Dr. Robert Adams – CEO
Optima Technology Group
[redacted] (b)(6)

REEDFAX
THE PATENT CONNECTION

United States Patent File History

Tab Listings

A. References (if applicable)
  A1–U.S. References
  A2–Foreign References

B. Jacket (face of file, contents flap, index of claims, PTO 270, searched)

C. Printed Patent

D. Specification (serial no. sheet, abstract, specification, claims)

E. Oath
  E1–Small Entity Status (if applicable)

F. Drawing Figures (if applicable)

G. PTO/Applicant Correspondence

H. Original Patent Application (in cases of FWC)

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01159

TO: Kelly Wright

Company Number: 3614
Account Number: 1306584
Client Reference: for BARRY GIBBENS-INTERFERENCE

Date: 05/16/2003

Patent Number: 5566073
File History

Comments: Overnight Courier

Address: Kelly Wright
NASA Langley Research Center
Office of Patent Counsel
Building 1229, 132E
MS 212
Hampton VA 236810001

Telephone Number: 757-864-2828

ISSUE CLASSIFICATION	
Class	Subclass
364	449

5566073

UTILITY SERIAL NUMBER	PATENT DATE	PATENT NUMBER
08/513298	OCT 1 5 1996	5566073

SERIAL NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	EXAMINER

APPLICANTS

ABN

TN

TN

Foreign priority claimed 35 USC 119 conditions met Verified and Acknowledged	☐ yes ☒ no / ☐ yes ☒ no / Examiner's initials	AS FILED	STATE OR COUNTRY	SHEETS DRWGS.	TOTAL CLAIMS	INDEP. CLAIMS	FILING FEE RECEIVED	ATTORNEY'S DOCKET NO.
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TITLE

Environment

#6 5-9-95

U.S. DEPT. OF COMM./PAT. & TM—PTO-436L (Rev.12-94)

PARTS OF APPLICATION FILED SEPARATELY

Applications Examiner

NOTICE OF ALLOWANCE MAILED		CLAIMS ALLOWED	
6-18-96	TAN NGUYEN Assistant Examiner	Total Claims 37	Print Claim 1

ISSUE FEE			DRAWING		
Amount Due	Date Paid		Sheets Drwg.	Figs. Drwg.	Print Fig.
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0116

08/513298

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PATENT APPLICATION

08513298

CONTENTS

Date Entered or Counted		Date Received or Mailed
	1. Application ✓ papers.	
	2. Pre Cond. C	9-9-95
	3. Pre Cond. D	9-9-95
	4. ~~Pre Cond. E Letter~~	10-20-95
1-2	5. Rejection - 3 months	1/22/96
	6. Examiner Interview Summary Record	3-15-96
4-22	7. Cond't E	4-19-96
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EXAMINER	49		8-10-94
TYPIST		519	8/16
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INDEX OF CLAIMS

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Claim Final	Claim Original	Date
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SYMBOLS

- ✓ .... Rejected
- = ... Allowed
- \- (Through numeral) Canceled
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- N .... Non-elected
- I .... Interference
- A .... Appeal
- O .... Objected

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STAPLE AREA

☆U.S.G.P.O.: 1994 - 378-972

PATENT NUMBER

APPLICATION SERIAL NUMBER
08/513,298

APPLICANT'S NAME (PLEASE PRINT)
MARGOLIN

IF REISSUE, ORIGINAL PATENT NUMBER

ORIGINAL CLASSIFICATION

CLASS	SUBCLASS
364	449

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)			
364	456	457		
340	990	995		
395	127	129		

INTERNATIONAL CLASSIFICATION

G	0	6	F		3	14
G	0	9	B		9	30

GROUP ART UNIT: 2304

ASSISTANT EXAMINER (PLEASE STAMP OR PRINT FULL NAME): TAN NGUYEN

PRIMARY EXAMINER (PLEASE STAMP OR PRINT FULL NAME): KEVIN J. TESKA SUPERVISORY PATENT EXAMINER GROUP 2300

PTO 270 (REV. 5-91)

ISSUE CLASSIFICATION SLIP

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

Claim Final	Claim Original	Date 12-[illegible]-95	Date 6-14-96	Date	Date	Date	Date	Date	Date
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Claim Final	Claim Original	Date	Date	Date	Date	Date	Date	Date	Date
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POSITION		ID NO.	DATE
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EXAMINER		2104?	9/23/95?
TYPIST		326?	9/1/?
VERIFIER			
CORPS CORR.			
SPEC. HAND			
FILE MAINT.			
DRAFTING			

INDEX OF CLAIMS

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- A .... Appeal
- O .... Objected

Claim Final	Claim Original	Date
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SEARCHED

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340	990, 995	12/11/95	TN
345	7, 11, 23, 27	12/11/95	TN
395	119, 124, 125, 127, 129	12/11/95	TN
update as above	search	06/14/96	TN

SEARCH NOTES

	Date	Exmr.
IEEE search	12/15/95	TN

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IEEE/IEE Publications Ondisc Jan 1988 - Sep 1995

Search Options:
   Search for both singular and plurals: YES
   Search for spelling variants        : NO
   Display intermediate result sets    : NO

 Num   Search                                              Hits
 #1    (elevation or altitud?) and data and base              9
 #2    terrain and (data or database)                       573
 #3    #1 and #2                                              3
 #4    digital terrain elevation data                         7
 #5    #4 or dted                                             9
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INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
364	449, 456, 457	06/14/96	TN
340	990, 995	06/14/96	TN
395	125, 127, 129	06/14/96	TN

(RIGHT OUTSIDE)

US005566073A

United States Patent [19]

Margolin

[11] **Patent Number: 5,566,073**

[45] **Date of Patent: Oct. 15, 1996**

2

[54] **PILOT AID USING A SYNTHETIC ENVIRONMENT**

[76] Inventor: **Jed Margolin**, 3570 Pleasant Echo Dr., San Jose, Calif. 95148-1916

[21] Appl. No.: **513,298**

[22] Filed: **Aug. 9, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 274,394, Jul. 11, 1994, abandoned.

[51] **Int. Cl.**[6] **G06F 3/14**; G09B 9/30

[52] **U.S. Cl.** **364/449**; 364/456; 364/457; 340/990; 340/995; 395/127; 395/129

[58] **Field of Search** 364/449, 455, 364/456, 457, 460; 340/990, 995; 345/7, 11, 23, 27; 395/119, 124, 125, 127, 129

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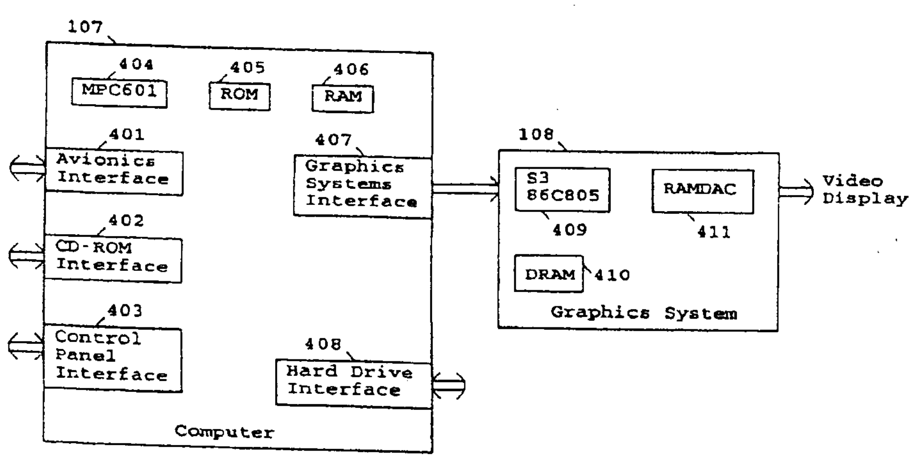
(List continued on next page.)

Primary Examiner—Kevin J. Teska
Assistant Examiner—Tan Nguyen
Attorney, Agent, or Firm—Blakely, Sokoloff, Taylor & Zafman

[57] **ABSTRACT**

A pilot aid using synthetic reality consists of a way to determine the aircraft's position and attitude such as by the global positioning system (GPS), a digital data base containing three-dimensional polygon data for terrain and manmade structures, a computer, and a display. The computer uses the aircraft's position and attitude to look up the terrain and manmade structure data in the data base and by using standard computer graphics methods creates a projected three-dimensional scene on a cockpit display. This presents the pilot with a synthesized view of the world regardless of the actual visibility. A second embodiment uses a head-mounted display with a head position sensor to provide the pilot with a synthesized view of the world that responds to where he or she is looking and which is not blocked by the cockpit or other aircraft structures. A third embodiment allows the pilot to preview the route ahead or to replay previous flights.

37 Claims, 13 Drawing Sheets



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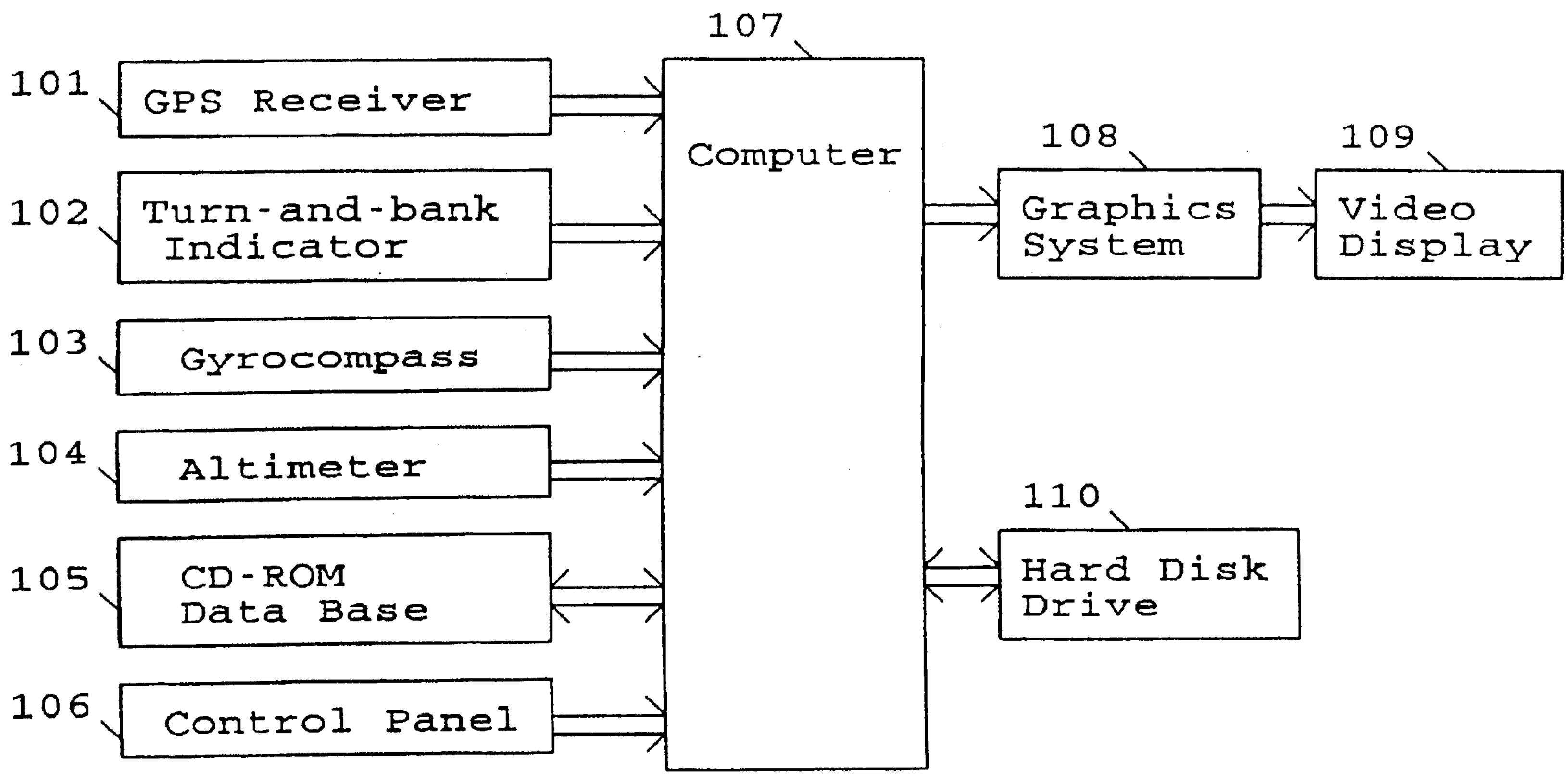
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Turn-and-bank Indicator
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Gyrocompass
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Altimeter
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CD-ROM Data Base
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Control Panel
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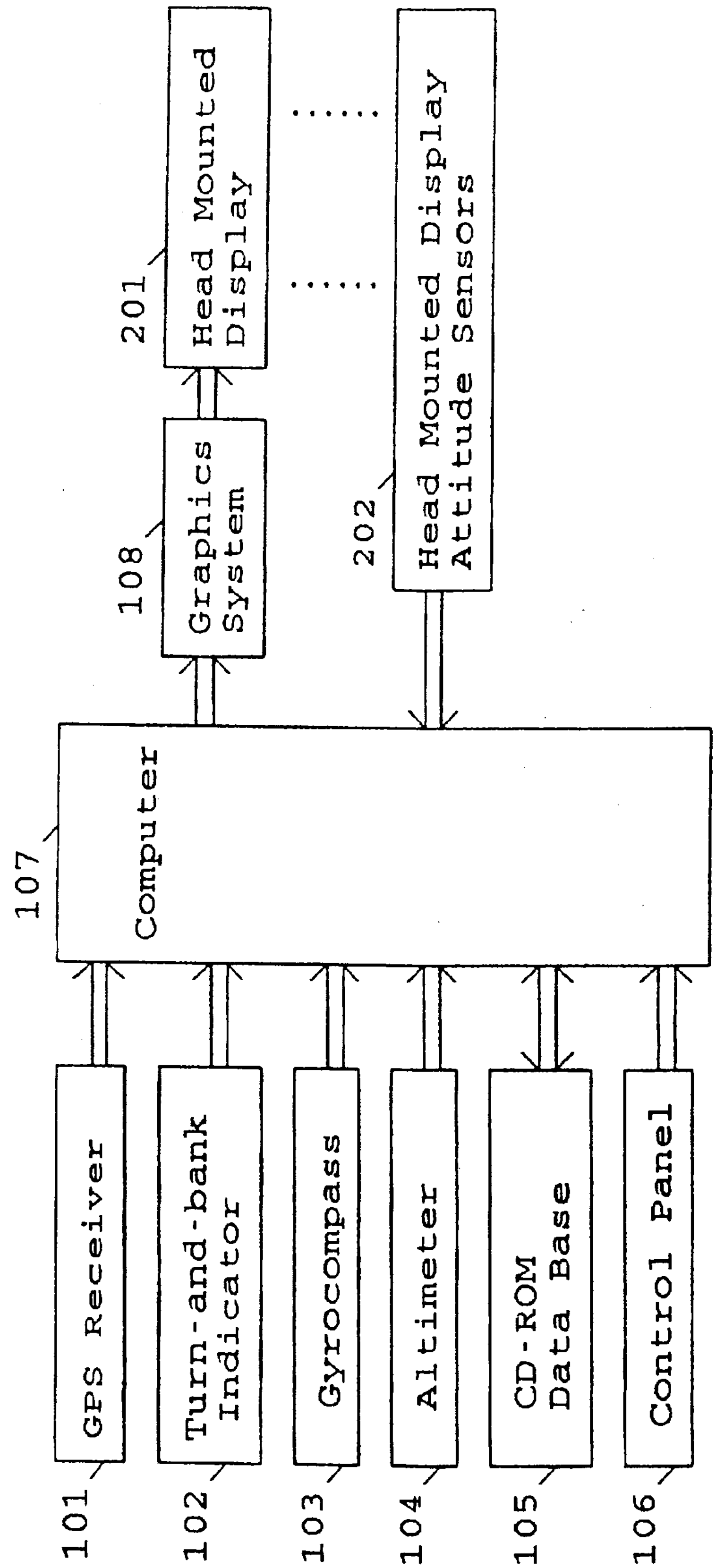
Computer
108
Graphics System
109
Video Display
110
Hard Disk Drive

Fig. 1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Head Mounted Display Attitude Sensors
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Altimeter
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CD-ROM Data Base
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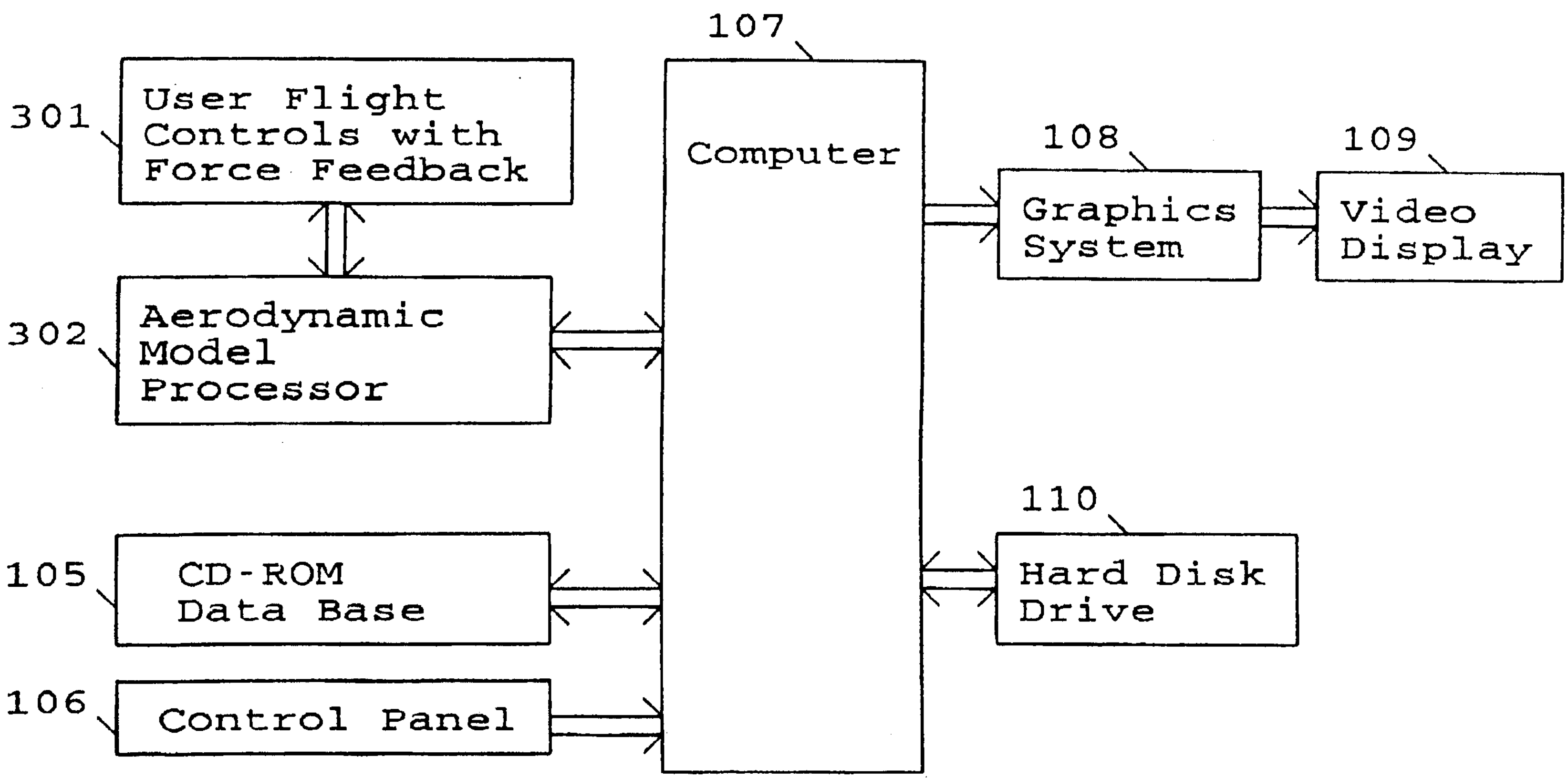
Control Panel
106

Fig. 2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302
Aerodynamic Model Processor
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CD-ROM Data Base
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Control Panel
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Computer
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Graphics System
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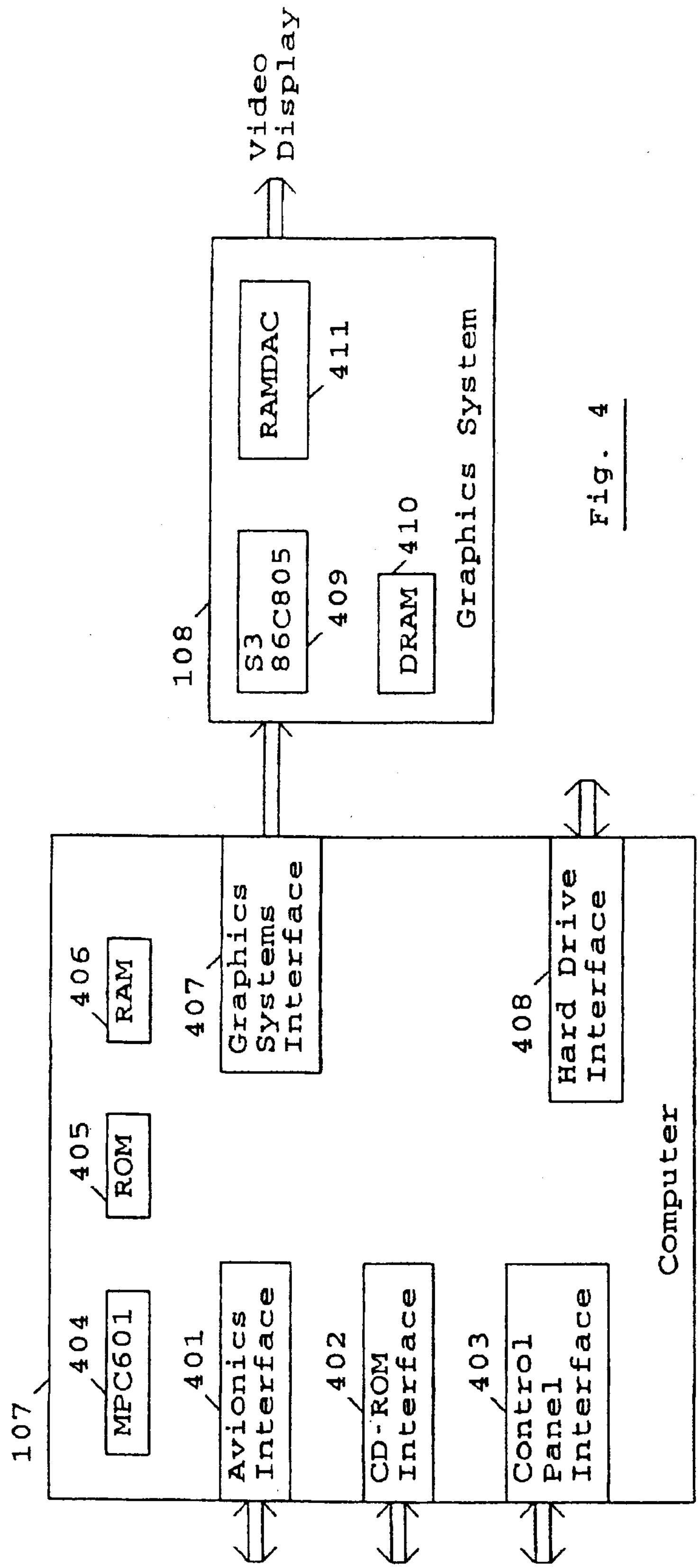
Video Display
110
Hard Disk Drive

Fig. 3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Control Panel Interface
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Graphics Systems Interface
407
Hard Drive Interface
408
Computer

Fig. 4

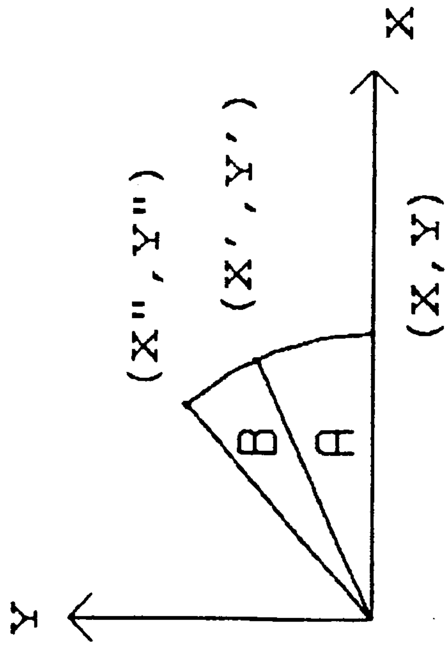
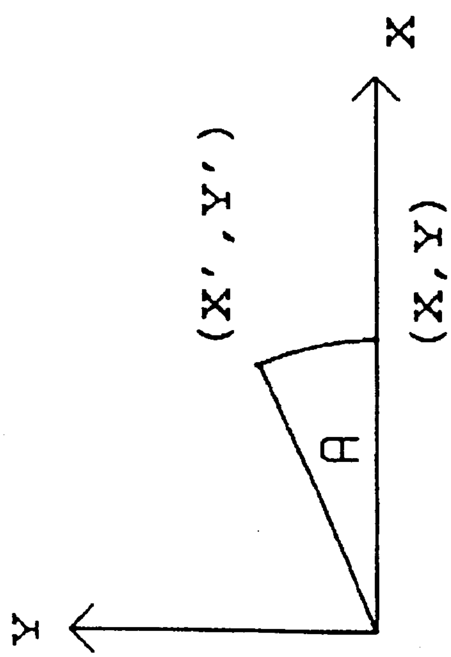


Fig. 5b



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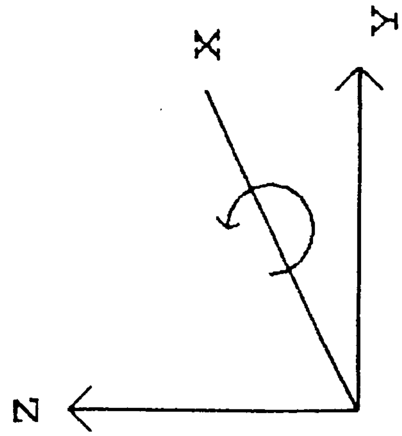


Fig. 6c

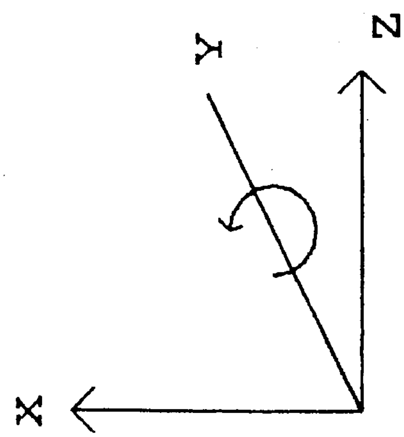
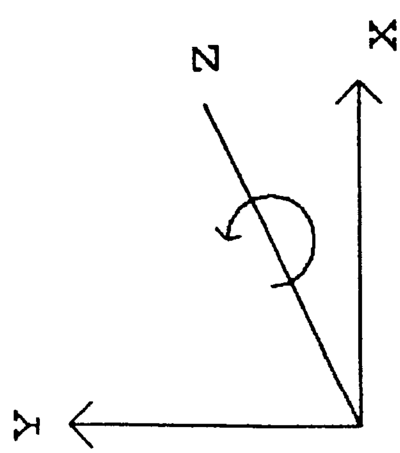


Fig. 6b



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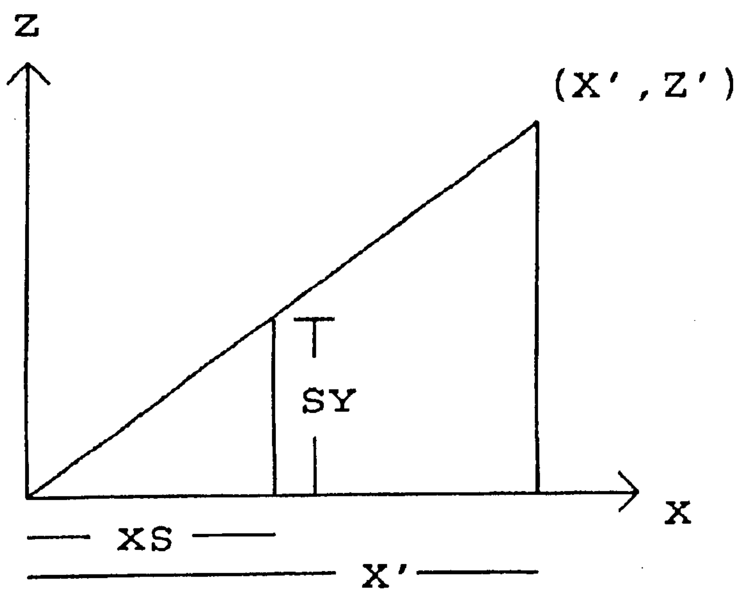


Fig. 7a Side

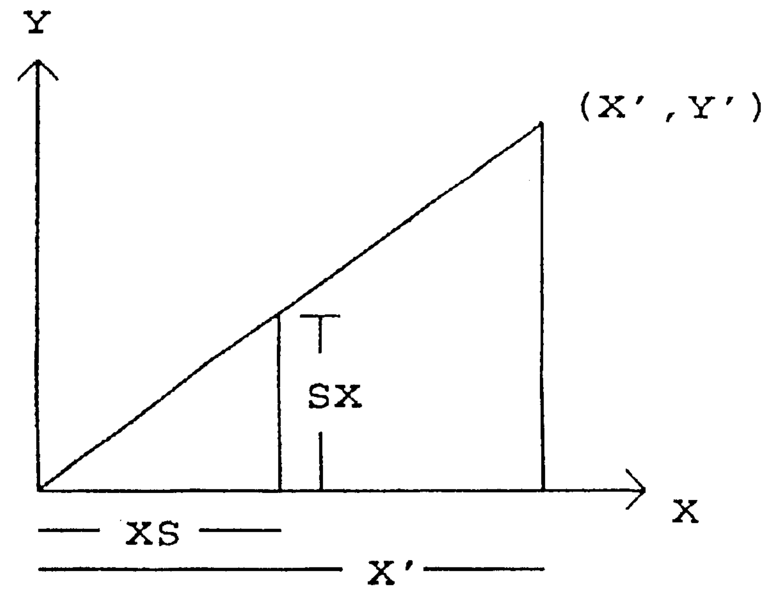


Fig. 7b Top

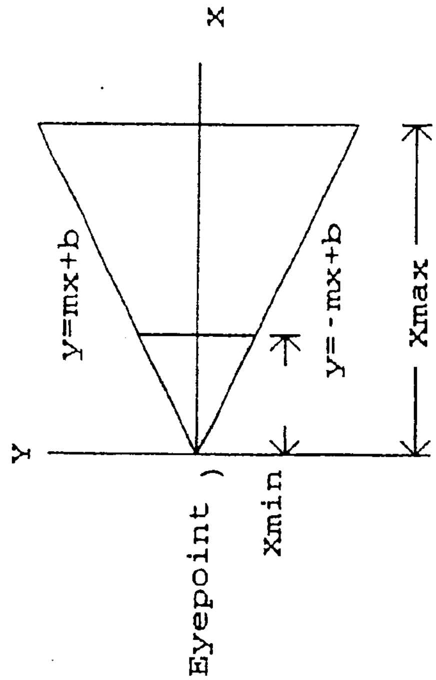


Fig. 8b Top View

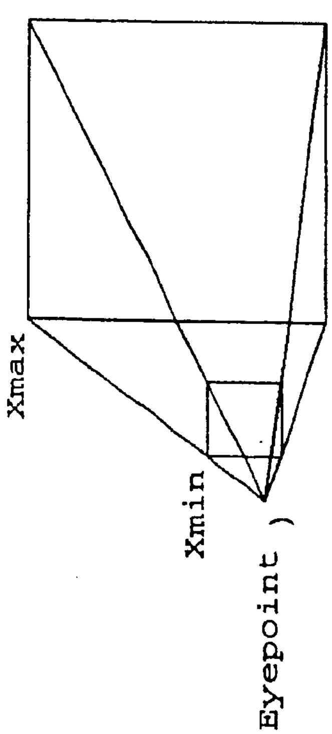


Fig. 8a

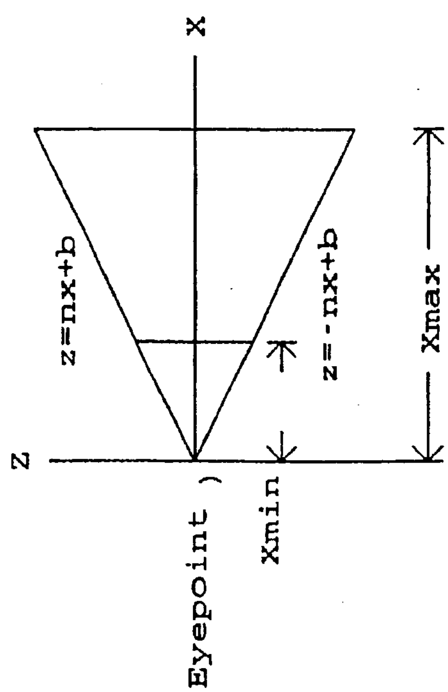
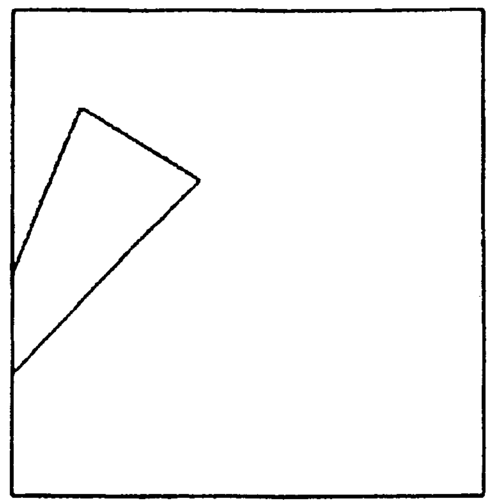


Fig. 8c Side View



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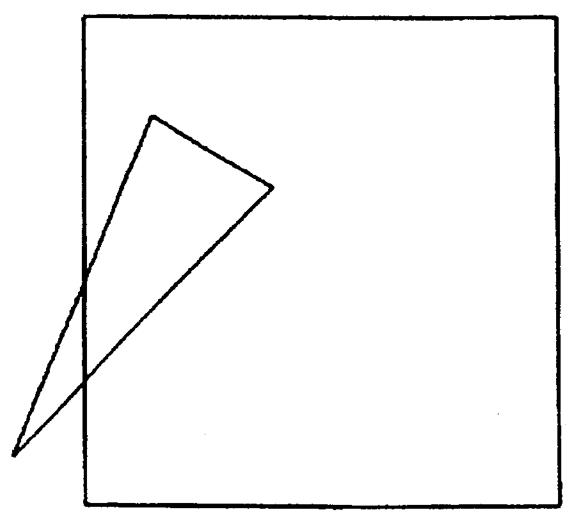

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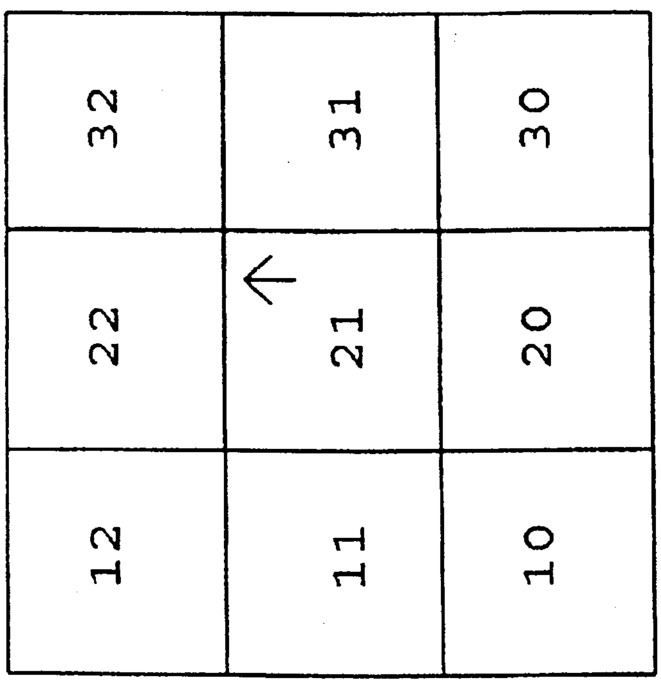

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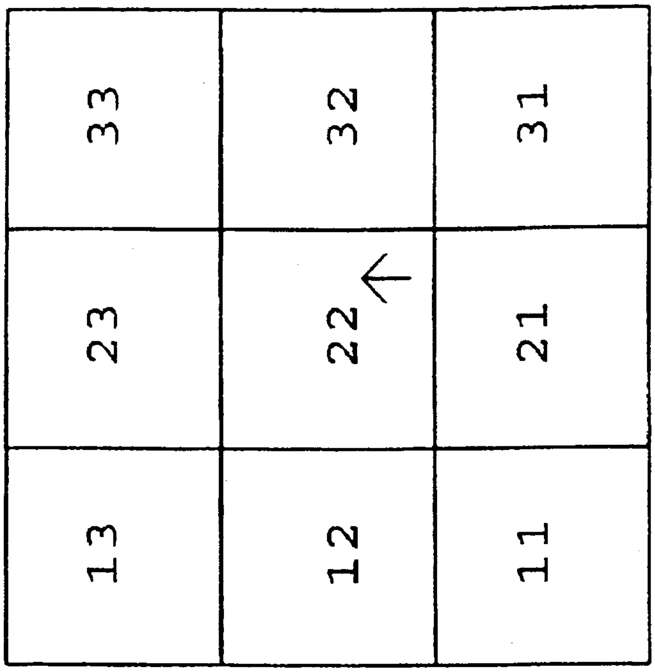

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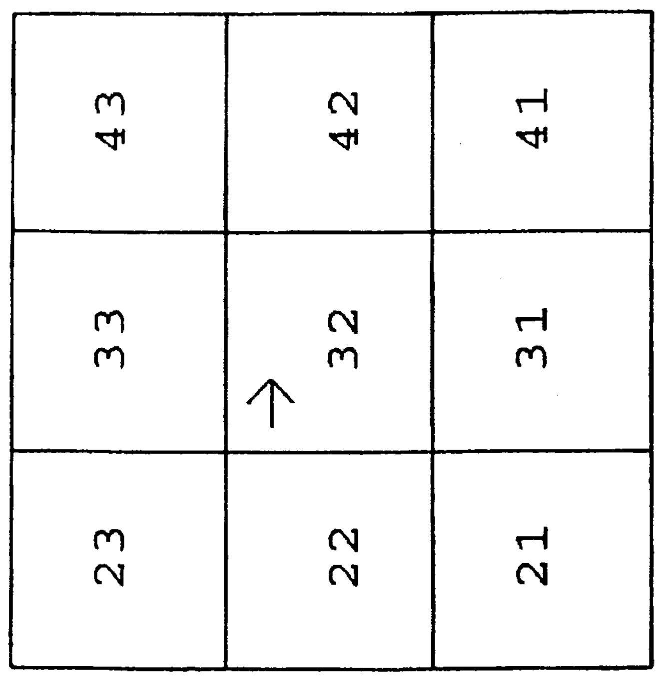

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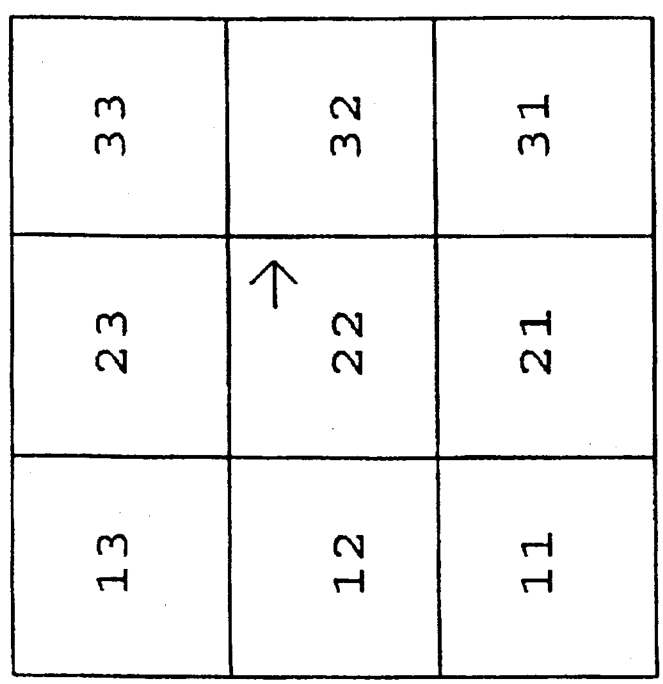

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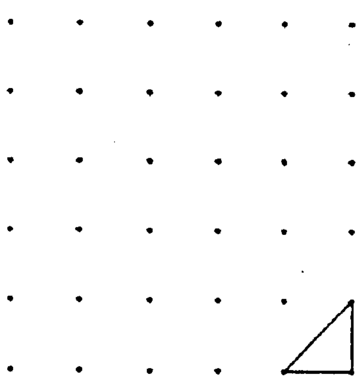

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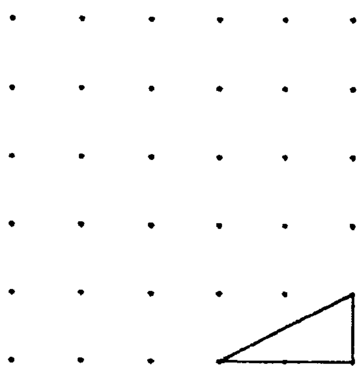

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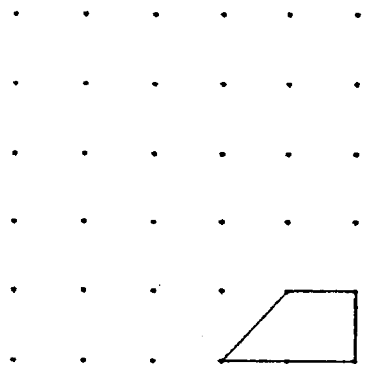

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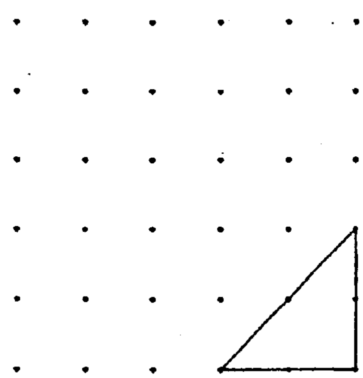

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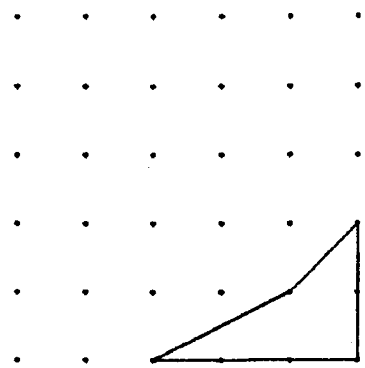

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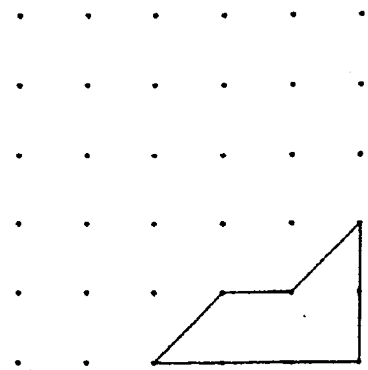

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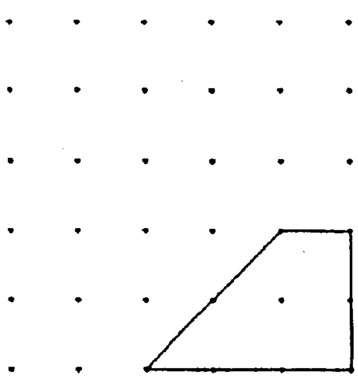

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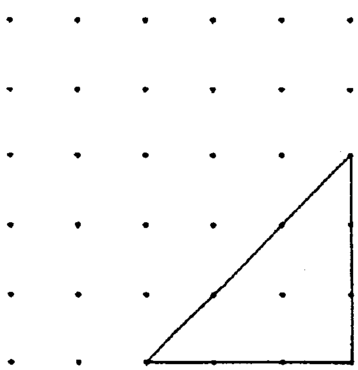

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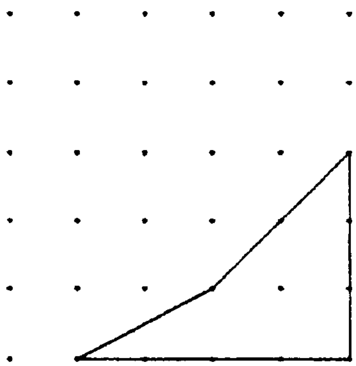

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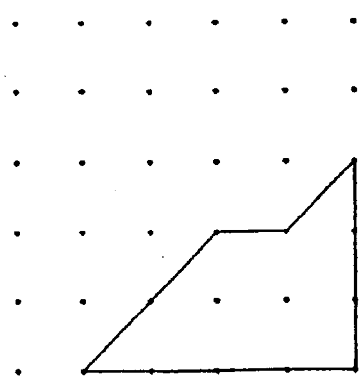

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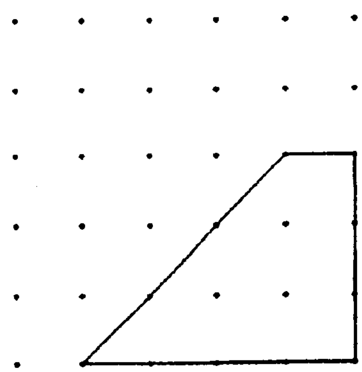

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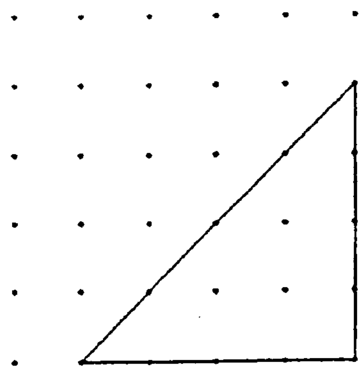

Fig. 13f

PILOT AID USING A SYNTHETIC ENVIRONMENT

This is a continuation of application Ser. No. 08/274,394, filed Jul. 11, 1994, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to a pilot aid for synthesizing a view of the world. When flying under Visual Flight Rules (VFR) the normal procedure for determining your position is to relate what you see out the window to the information on a paper map. During the day it can be difficult to determine your location because the desired landmark can be lost in the clutter of everything else. When flying at night you see mostly lights. When flying under Instrument Flight Rules (IFR) you must relate the information from various navigation aids to the information on a printed map. You must then interpret the map information in order to avoid flying into objects such as mountains and the like. An improvement in this situation came about when the global positioning system (GPS) became operational and available for civilian use. GPS directly provides map coordinates but you must still, however, interpret the map information. Systems have been developed which use GPS coordinates to access an electronic map which is presented on a display as a flat map. Systems have also been developed that present an apparent three-dimensional effect and some that present a mathematically correct texture-mapped three-dimensional projected display.

Both of these systems require a very large amount of storage for terrain data. The latter system also requires specialized hardware. Their high cost have prevented their widespread adoption by the avaiation community.

The 1984 patent to Taylor et al. (U.S. Pat. No. 4,445,118) shows the basic operation of the global positioning system (GPS).

The 1984 patent to Johnson et al. (U.S. Pat. No. 4,468, 793) shows a receiver for receiving GPS signals.

The 1984 patent to Maher (U.S. Pat. No. 4,485,383) shows another receiver for receiving GPS signals.

The 1986 patent to Evans (U.S. Pat. No. 4,599,620) shows a method for determining the orientation of a moving object and producing roll, pitch, and yaw information.

The 1992 patent to Timothy et al. (U.S. Pat. No. 5,101, 356) also shows a method for determining the orientation of a moving object and producing roll, pitch, and yaw information.

The 1993 patent to Ward et al. (U.S. Pat. No. 5,185,610) shows a method for determining the orientation of a moving object from a single GPS receiver and producing roll, pitch, and yaw information.

The 1992 patent to Fraughton et al. (U.S. Pat. No. 5,153,836) shows a navigation, surveillance, emergency location, and collision avoidance system and method whereby each craft determines its own position using LORAN or GPS and transmits it on a radio channel along with the craft's identification information. Each craft also receives the radio channel and thereby can determine the position and identification of other craft in the vicinity.

The 1992 patent to Beckwith et al. (U.S. Pat. No. 5,140, 532) provides a topographical two-dimensional real-time display of the terrain over which the aircraft is passing, and a slope-shading technique incorporated into the system provides to the display an apparent three-dimensional effect similar to that provided by a relief map. This is accomplished by reading compressed terrain data from a cassette tape in a controlled manner based on the instantaneous geographical location of the aircraft as provided by the aircraft navigational computer system, reconstructing the compressed data by suitable processing and writing the reconstructed data into a scene memory with a north-up orientation. A read control circuit then controls the read-out of data from the scene memory with a heading-up orientation to provide a real-time display of the terrain over which the aircraft is passing. A symbol at the center of display position depicts the location of the aircraft with respect to the terrain, permitting the pilot to navigate the aircraft even under conditions of poor visibility. However, the display provided by this system is in the form of a moving map rather than a true perspective display of the terrain as it would appear to the pilot through the window of the aircraft.

The 1987 patent to Beckwith et al. (U.S. Pat. No. 4,660, 157) is similar to U.S. Pat. No. 5,140,532. It also reads compressed terrain data from a cassette tape in a controlled manner based on the instantaneous geographical location of the aircraft as provided by the aircraft navigational computer system and reconstructs the compressed data by suitable processing and writing the reconstructed data into a scene memory. However, instead of providing a topographical two-dimensional display of the terrain over which the aircraft is passing and using a slope-shading technique to provide an apparent three-dimensional effect similar to that provided by a relief map as shown in the '532 patent, the '157 patent processes the data to provide a 3D perspective on the display. There are a number of differences between the '157 patent and the present invention:

1. The '157 Patent stores the map as a collection of terrain points with associated altitudes; the large amount of storage required by this approach requires that a tape be prepared for each mission. The present invention stores terrain data as a collection of polygons which results in a significant reduction of data base storage; larger geographic areas can be stored so that it it not necessary to generate a data base for each mission.
2. The '157 Patent uses a tape cassette for data base storage; the long access time for tape storage makes it necessary to use a relatively large cache memory. The present invention uses a CD-ROM which permits random access to the data so that the requirements for cache storage are reduced.
3. The '157 Patent accounts for the aircraft's heading by controlling the way the data is read out from the tape. Different heading angles result in the data being read from a different sequence of addresses. Since addresses exist only at discrete locations, the truncation of address locations causes an unavoidable change in the map shapes as the aircraft changes heading. The present invention stores terrain as polygons which are mathematically rotated as the aircraft changes attitude. The resolution is determined by number of bits used to represent the vertices of the polygons, not the number of storage addresses.
4. The '157 accounts for the roll attitude of the aircraft by mathematically rotating the screen data after it is projected. The '157 Patent does not show the display being responsive to the pitch angle of the aircraft. In systems such as this the lack of fidelity is apparent to the user. People know what things are supposed to look like and how they are supposed to change perspective when they move. The present invention uses techniques that

have long been used by the computer graphics industry to perform the mathematically correct transformation and projection.

5. The '157 shows only a single cockpit display while one of the embodiments of the present invention shows a stereographic head-mounted display with a head sensor. The pilot is presented with a synthesized view of the world that is responsive to wherever the pilot looks; the view is not blocked by the cockpit or other aircraft structures. This embodiment is not anticipated by the '157 patent.

The 1991 patent to Behensky et al. (U.S. Pat. No. 5,005,148) shows a driving simulator for a video game. The road and other terrain are produced by mathematically transforming a three-dimensional polygon data base.

The first sales brochure from Atari Games Corp. is for a coin-operated game (Hard Drivin') produced in 1989 and relates to the '148 patent. The terrain is represented by polygons in a three-dimensional space. Each polygon is transformed mathematically according to the position and orientation of the player. After being tested to determine whether it is visible and having the appropriate illumination function performed, it is clipped and projected onto the display screen. These operations are in general use by the computer graphics industry and are well known to those possessing ordinary skill in the art.

The second sales brochure from Atari Games Corp. is for a coin-operated game (Steel Talons) produced in 1991 and which also relates to the '148 patent and the use of polygons to represent terrain and other objects.

The 1993 patent to Dawson et al. (U.S. Pat. No. 5,179,638) shows a a method and apparatus for providing a texture mapped perspective view for digital map systems which includes a geometry engine that receives the elevation posts scanned from the cache memory by the shape address generator. A tiling engine is then used to transform the elevation posts into three-dimensional polygons. There are a number of differences between the '638 patent and the present invention:

1. The '638 Patent is for a digital map system only. The matter of how the location and attitude are selected is not addressed. The present invention uses a digital map as part of a system for presenting an aircraft pilot with a synthesized view of the world regardless of the actual visibility.
2. The '638 Patent stores the map as a collection of terrain points with associated altitudes, thereby requiring a large amount of data storage. The terrain points are transformed into polygons during program run-time thereby adding to the processing burden. The present invention stores terrain data as a collection of polygons which results in a significant reduction of data base storage.
3. The present invention also teaches the use of a stereographic head-mounted display with a head sensor. The pilot is presented with a synthesized view of the world that is responsive to wherever the pilot looks; the view is not blocked by the cockpit or other aircraft structures. This embodiment is not anticipated by the '638 patent.

The 1994 patent to Hamilton et al. (U.S. Pat. No. 5,296,854) shows a helicopter virtual display system in which the structual outlines corresponding to structual members forming the canopy structure are added to the head-up display in order to replace the canopy structure clues used by pilots which would otherwise be lost by the use of the head-up display.

The 1994 patent to Lewins (U.S. Pat. No. 5,302,964) shows a head-up display for an aircraft and incorporates a cathode-ray tube image generator with a digital look-up table for distortion correction. An optical system projects an image formed on the CRT screen onto a holographic mirror combiner which is transparent to the pilot's direct view through the aircraft windshield.

The sales brochure from the Polhemus company shows the commercial availability of a position and orientation sensor which can be used on a head-mounted display.

The article from EDN magazine, Jan. 7, 1993, pages 31–42, entitled "System revolutionizes surveying and navigation" is an overview of how the global positioning system (GPS) works and lists several manufacturers of commercially available receivers. The article also mentions several applications such as the use by geologists to monitor fault lines, by oil companies for off-shore oil explorations, for keeping track of lower-orbit satellites, by fleet vehicle operators to keep track of their fleet, for crop sprayers to spread fertilizer and pesticides more efficiently, and for in-car systems to display maps for automotive navigation.

The section from "Aviator's Guide to GPS" presents a history of the GPS program.

The sales brochure from Megellan Systems Corp. is for commercially available equipment comprising a GPS receiver with a moving map display. The map that is displayed is a flat map.

The sales brochure from Trimble Navigation is for a commercially available GPS receiver.

The sales brochure from the U.S. Geological survey shows the availability of Digital Elevation Models for all of the United States and its territories.

The second sales brochure from the U.S. Geological survey shows the availability of Digital Line Graph Models for all of the United States and its territories. The data includes: political and administrative boundaries; hydrography consisting of all flowing water, standing water, and wetlands; major transportation systems consisting of roads and trails, railroads, pipelines, transmission lines, and airports; and significant manmade structures.

The Washington Sectional Aeronautical Chart is a paper map published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration that shows the complexity of the information that an aircraft pilot needs in order to fly in the area covered by the map. The other areas of the U.S. are covered by similar maps.

The sales brochure from Jeppesen Sanderson shows that the company makes its navigation data base available in computer readable form.

Accordingly, several objects and advantages of my invention are to provide a system that produces a mathematically correct three-dimensional projected view of the terrain while reducing the amount of storage required for the data base and which can be accomplished by using standard commercially available components. The invention can be used as a real-time inflight aid or it can be used to preview a flight, or it can be used to replay and review a previous flight.

Further objects and advantages of my invention will become apparent from a consideration of the drawings and ensuing description.

SUMMARY OF THE INVENTION

The present invention is a pilot aid which uses the aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three-dimensional projected view of the world. The three-dimensional position is typically determined by using the output of a commercially available GPS receiver. As a safety check, the altitude calculated by the GPS receiver can be compared to the output of either a standard altimeter or a radio altimeter. Attitude can also be determined from the use of a GPS receiver or it can be derived from standard avionic instruments such as turn-and-bank indicator and gyrocompass. The digital data base represents the terrain and manmade structures as collections of polygons in order to minimize storage requirements. The pilot can select several feature such as pan, tilt, and zoom which would allow the pilot to see a synthesized view of terrain that would otherwise be blocked by the aircraft's structure, especially on a low-wing aircraft. The pilot can also preview the route either inflight or on the ground. Because the system has the ability to save the flying parameters from a flight, the pilot can replay all or part of a previous flight, and can even take over during the replay to try out different flight strategies. Through the use of a head-mounted display with a head sensor, the pilot can have complete range of motion to receive a synthesized view of the world, completely unhindered by the aircraft structure.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing the output to a single video display.

FIG. **2** is a block diagram showing the output to a head-mounted display.

FIG. **3** is a block diagram showing a system used to plan and/or replay a particular flight.

FIG. **4** is a block diagram showing Computer **107** and Graphics System **108** in FIG. **1**, FIG. **2**, and FIG. **3**.

FIG. *5a* shows a simple positive (counter-clockwise) rotation of a point around the origin of a 2-Dimensional space.

FIG. *5b* shows a second positive (counter-clockwise) rotation of a point around the origin of a 2-Dimensional space.

FIG. **6***a* shows the equivalent three dimensional space of FIG. *5a* where the rotation is around the Z axis.

FIG. **6***b* is a re-orientation of the axes of FIG. **6***a* showing rotation around the Y axis.

FIG. **6***c* is a re-orientation of the axes of FIG. **6***a* showing rotation around the X axis.

FIG. *7a* is a side view showing the projection of a point in three-dimensions projected onto a two-dimensional screen.

FIG. *7b* is a top view showing the projection of a point in three-dimensions projected onto a two-dimensional screen.

FIG. *8a* is a cabinet-projected three-dimensional representation of the viewing pyramid.

FIG. *8b* is a 2D top view of the viewing pyramid.

FIG. *8c* is a 2D side view of the viewing pyramid.

FIG. *9a* shows an unclipped polygon.

FIG. *9b* shows how clipping the polygon in FIG. *9a* produces additional sides to the polygon.

FIG. **10***a* shows the impending crossover from Geographic Data Block **21** to Geographic Data Block **22**.

FIG. **10***b* shows the result of a crossover from Geographic Data Block **21** to Geographic Data Block **22**.

FIG. **11***a* shows the impending crossover from Geographic Data Block **22** to Geographic Data Block **32**.

FIG. **11***b* shows the result of a crossover from Geographic Data Block **22** to Geographic Data Block **32**.

FIG. **12***a* through FIG. **12***f*, and FIG. **13***a* through FIG. **13***f* show the procedure for generating the polygon data base from the Digital Elevation Model data.

DETAILED SPECIFICATION

FIG. **1** shows the basic form of the invention. GPS Receiver **101** receives signals from the satellites that make up the global positioning system (GPS) and calculates the aircraft's position in three dimensions. Altimeter **104** provides an output of the aircraft's altitude as a safety check in the event GPS Receiver **101** malfunctions. Turn-and-bank Indicator **102** and Gyrocompass **103** provide the aircraft's attitude which comprises heading, roll, and pitch. CD-ROM Data Base **105** contains the digital data base consisting of three-dimensional polygon data for terrain and manmade structures.

Computer **107** is shown in more detail in FIG. **4** and uses commercially available integrated circuits including processor **404**, the MPC601, from Motorola Semiconductor Inc. The MPC601 is a fast 32-bit RISC processor with a floating point unit and a 32K Byte eight-way set-associative unified instruction and data cache. Most integer instructions are executed in one clock cycle. Compilers are available for ANSI standard C and for ANSI standard FORTRAN 77. Computer **107** also contains ROM **405**, RAM **406**, Avionics Interface **401**, CD-ROM Interface **402**, Control Panel Interface **403**, Graphics Systems Interface **407**, and Hard Drive Interface **408**.

Computer **107** uses the aircraft's position from GPS Receiver **101** to look up the terrain and manmade structure data in CD-ROM Data Base **105**. This data is organized in geographic blocks and is accessed so that there is always the proper data present. This is shown in FIG. **10***a*. FIG. **10***b* shows that when the aircraft crosses from Block **21** to Block **22**, the data from Blocks **10**, **20**, and **30** are discarded and data from Blocks **13**, **23**, and **33** are brought in from CD-ROM Data Base **105**. FIG. **11***a* and FIG. **11***b* show the aircraft crossing from Block **22** to Block **32**.

Computer **107** uses the aircraft's position from GPS Receiver **101** and attitude information from Turn-and-bank Indicator **102** and Gyrocompass **103** to mathematically operate on the terrain and manmade structure data to present three-dimensional projected polygons to Graphics System **108**. As shown in FIG. **4**, Graphics System **108** consists of a commercially available graphics integrated circuit **409**, the 86C805, made by S3 Incorporated. This integrated circuit contains primitives for drawing lines in addition to the standard SVGA graphics functions. The 86C805 controls DRAM **410** which is the video memory consisting of two buffers of 1024×768 pixels, each of which is 8 bits deep. The video to be displayed from DRAM **410** is sent to RAMDAC **411** which is an integrated circuit commercially available from several manufacturers, such as Brooktree and AT&T. RAMDAC **411** contains a small RAM of 256×24 bits and three 8-bit DACs. The RAM section is a color table programmed to assign the desired color to each of the 256 combinations possible by having 8 bits/pixel and is combined with three video DACs, one for each color for Video Display **109**.

Video Display **109** is a color video display of conventional design such as a standard CRT, an LCD panel, or a plasma display panel. The preferred size of Video Display **109** is 19" although other sizes may be used.

FIG. **2** shows the use of the system with Head Mounted Display **201**. Head Mounted Display Attitude Sensors **202** provide Computer **107** with the orientation of Head Mounted Display **201**. This orientation is concatenated with the aircraft's orientation provided by Turn-and-bank Indicator **102** and Gyrocompass **103**. As a consequence the pilot can turn his or her head and view the three-dimensional synthesized view of the transformed terrain and manmade structure data unhindered by the aircraft's structure. With the appropriate sensors for engines, fuel tanks, doors, and the like, the pilot can be presented with synthesized representations of these objects in their correct locations. For example, the pilot would be able to 'look' at a fuel tank and 'see' if it is running low. The pilot would also be able to 'see' if there is a problem with an engine and, on multi-engine aircraft, identify which one. By using a technique similar to that taught in the 1992 patent to Fraughton et al. (U.S. Pat. No. 5,153,836) where each aircraft determines its own position using LORAN or GPS and transmits it on a radio channel along with the aircraft's identification information so that each craft also receives the radio channel and can thereby determine the position and identification of other craft in the vicinity, these other aircraft can be presented in the present invention as three-dimensional objects in their correct positions to alert the pilot to their presence and take evasive maneuvers as required.

Hard Disk Drive **110** is for recording the aircraft's position and orientation data for later playback in order to review the flight. Because the information presented on Video Display **109** is a function of the aircraft's position and orientation data applied to the CD-ROM Data Base **105**, it can be reconstructed later at any time by storing just the aircraft's position and orientation data and applying it again to CD-ROM Data Base **106**, as long as the data base is still available. The aircraft's position and orientation data requires fewer than 100 bytes. By recording it every 0.1 seconds, an hour requires about 3.6 Megabytes of storage. (100 bytes/update×10 updates/second×60 seconds/min×60 minutes/hour=about 3.6 Megabytes) Therefore, a standard 340 Megabyte hard drive would store about 94 hours of operation.

A method for previewing a route that has not been flown before is shown in FIG. 3. GPS Receiver **101**, Turn-and-bank Indicator **102**, Gyrocompass **103**, and Altimeter **104** are replaced by User Flight Controls with Force Feedback **301** and Aerodynamic Model Processor **302**. Aerodynamic Model Processor **302** is a processor that implements the aerodynamic mathematical model for the type of aircraft desired. It receives the user inputs from User Flight Control with Force Feedback **301**, performs the mathematical calculations to simulate the desired aircraft, and supplies output back to the Force Feedback part of the controls and to Computer **107**. The outputs supplied to Computer **107** simulate the outputs normally supplied to GPS Receiver **101**, Turn-and-bank Indicator **102**, Gyrocompass **103**, and Altimeter **104**. In this way, Computer **107** executes exactly the same program that it would perform in the in-flight system. This permits the pilot to practice flying routes that he or she has not flown before and is particularly useful in practicing approach and landing at unfamiliar airports. This system does not need to be installed in an aircraft; it can be installed in any convenient location, even the pilot's home.

Control Panel **106** allows the pilot to select different operating features. For example, the pilot can choose the 'look angle' of the display (pan and tilt). This would allow the pilot to see synthesized terrain coresponding to real terrain that would otherwise be blocked by the aircraft's structure like the nose, or the wing on a low wing aircraft. Another feature is the zoom function which provides magnification. Another feature is to permit the pilot to select a section of the route other than the one he or she is on, for example, to preview the approach to the destination airport.

MATH INTRO

The math for the present invention has been used in the field of coin-operated video games and in traditional computer graphics. However, since it has not been well documented, it will be presented here. The basic concept assumes the unit is a simulator, responsive to the user's inputs. It is a short step from that to the present invention where the inputs represent the physical location and attitude of the aircraft.

The steps required to view a 3D polygon-based data base are:

1. Transformation (translation and rotation as required)
2. Visibility and illumination
3. Clipping
4. Projection

In this geometric model there is an absolute Universe filled with Objects, each of which is free to rotate and translate. Associated with each Object is an Orthonormal Matrix (i.e. a set of Orthogonal Unit Vectors) that decribes the Object's orientation with respect to the Universe. Because the Unit Vectors are Orthogonal, the Inverse of the matrix is simply the Transpose. This makes it very easy to change the point of reference. The Object may look at the Universe or the Universe may look at the Object. The Object may look at another Object after the appropriate concatenation of Unit Vectors. Each Object will always Roll, Pitch, or Yaw around its own axes regardless of its current orientation without using Euler angle functions.

ROTATIONS

The convention used here is that the Z axis is straight up, the X axis is straight ahead, and the Y axis is to the right. ROLL is a rotation around the X axis, PITCH is a rotation around the Y axis, and YAW is a rotation around the Z axis.

For a simple positive (counter-clockwise) rotation of a point around the origin of a 2-Dimensional space:

$$X'=X*COS(a)-Y*SIN(a)$$

$$Y'=X*SIN(a)+Y*COS(a)$$

See FIG. 5*a*.

If we want to rotate the point again there are two choices:

1. Simply sum the angles and rotate the original points, in which case:

$$X''=X*COS(a+b)-Y*SIN(a+b)$$

$$Y''=X*SIN(a+b)+Y*COS(a+b)$$

2. Rotate X', Y' by angle b:

$$X''=X'*COS(b)-Y'*SIN(b)$$

$$Y''=X'*SIN(b)+Y'*COS(b)$$

See FIG. 5*b*.

With the second method the errors are cumulative. The first method preserves the accuracy of the original coordinates; unfortunately it works only for rotations around a single axis. When a series of rotations are done together around two or three axes, the order of rotation makes a difference. As an example: An airplane always Rolls, Pitches, and Yaws according to its own axes. Visualize an airplane suspended in air, wings straight and level, nose pointed North. Roll 90 degrees clockwise, then pitch 90 degrees "up". The nose will be pointing East. Now we will start over and reverse the order of rotation. Start from straight and level, pointing North. Pitch up 90 degrees, then Roll 90 degrees clockwise, The nose will now be pointing straight up, where "up" is referenced to the ground. If you have trouble visualizing these motions, Just pretend your hand is the airplane.

This means that we cannot simply keep a running sum of the angles for each axis. The standard method is to use functions of Euler angles. The method to be described is easier and faster to use than Euler angle functions.

Although FIG. 5*a* represents a two dimensional space, it is equivalent to a three dimensional space where the rotation is around the Z axis. See FIG. 6*a*. The equations are:

$$X' = X*COS(za) - Y*SIN(za) \qquad \text{Equation 1}$$
$$Y' = X*SIN(za) + Y*COS(za)$$

By symmetry the other equations are:

$$Z' = Z*COS(ya) - X*SIN(ya) \qquad \text{Equation 2}$$
$$X' = Z*SIN(ya) + X*COS(ya)$$

See FIG. 6b.

and

$$Y' = Y*COS(xa) - Z*SIN(xa) \qquad \text{Equation 3}$$
$$Z' = Y*SIN(xa) + Z*COS(xa)$$

See FIG. 6c.

From the ship's frame of reference it is at rest; it is the Universe that is rotating. We can either change the equations to make the angles negative or decide that positive rotations are clockwise. Therefore, from now on all positive rotations are clockwise.

Consolidating Equations 1, 2, and 3 for a motion consisting of rotations za (around the Z axis), ya (around the Y axis), and xa (around the X axis) yields:

X'=X*[COS(ya)*COS(za)]+Y*[−COS(ya)*SIN(za)]+Z*[SIN(ya)]

Y'=X*[SIN(xa)*SIN(ya)*COS(za)+COS(xa)*SIN(za)]+Y*[−SIN(xa)*SIN(ya)*SIN(za)+COS(xa)*COS(za)]+Z*[−SIN(xa)*COS(ya)]

Z'=X*[−COS(xa)*SIN(ya)*COS(za)+SIN(xa)*SIN(za)]+Y*[COS(xa)*SIN(ya)*SIN(za)+SIN(xa)*COS(za)]+Z*[COS(xa)*COS(ya)]

(The asymmetry in the equations is another indication of the difference the order of rotation makes.)

The main use of the consolidated equations is to show that any rotation will be in the form:

$$X' = Ax*X + Bx*Y + Cx*Z$$

$$Y' = Ay*X + By*Y + Cy*Z$$

$$Z' = Az*X + Bz*Y + Cz*Z$$

If we start with three specific points in the initial, absolute coordinate system, such as:

Px=(1,0,0)

Py=(0,1,0)

Pz=(0,0,1)

after any number of arbitrary rotations,

Px'=(XA,YA,ZA)

Py'=(XB,YB,ZB)

Pz'=(XC,YC,ZC)

By inspection:

$$XA = Ax \quad XB = Bx \quad XC = Cx$$
$$YA = Ay \quad YB = By \quad YC = Cy$$
$$ZA = Az \quad ZB = Bz \quad ZC = Cz$$

Therefore, these three points in the ship's frame of reference provide the coefficients to transform the absolute coordinates of whatever is in the Universe of points. The absolute list of points is itself never changed so it is never lost and errors are not cumulative. All that is required is to calculate Px, Py, and Pz with sufficient accuracy. Px, Py, and Pz can be thought of as the axes of a gyrocompass or 3-axis stabilized platform in the ship that is always oriented in the original, absolute coordinate system.

TRANSLATIONS

Translations do not affect any of the angles and therefore do not affect the rotation coefficients. Translations will be handled as follows:

Rather than keep track of where the origin of the absolute coordinate system is from the ship's point of view (it changes with the ship's orientation), the ship's location will be kept track of in the absolute coordinate system.

To do this requires finding the inverse transformation of the rotation matrix. Px, Py, and Pz are vectors, each with a length of 1.000, and each one orthogonal to the others. (Rotating them will not change these properties.) The inverse of an orthonormal matrix (one composed of orthogonal unit vectors like Px, Py, and Pz) is formed by transposing rows and columns.

Therefore, for X, Y, Z in the Universe's reference and X', Y', Z' in the Ship's reference:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \text{ and}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} Ax & Ay & Az \\ Bx & By & Bz \\ Cx & Cy & Cz \end{bmatrix} * \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

The ship's X unit vector (1,0,0), the vector which, according to the ship is straight ahead, transforms to (Ax,Bx,Cx). Thus the position of the ship in terms of the Universe's coordinates can be determined. The complete transformation for the Ship to look at the Universe, taking into account the position of the Ship: For X,Y,Z in Universe reference and X', Y', Z' in Ship's reference

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X - XT \\ Y - YT \\ Z - ZT \end{bmatrix}$$

INDEPENDENT OBJECTS

To draw objects in a polygon-based system, rotating the vertices that define the polygon will rotate the polygon.

The object will be defined in its own coordinate system (the object "library") and have associated with it a set of unit vectors. The object is rotated by rotating its unit vectors. The object will also have a position in the absolute Universe.

When we want to look at an object from any frame of reference we will transform each point in the object's library by applying a rotation matrix to place the object in the proper orientation. We will then apply a translation vector to place the object in the proper position. The rotation matrix is derived from both the object's and the observer's unit vectors; the translation vector is derived from the object's position, the observer's position, and the observer's unit vectors.

The simplest frame of reference from which to view an object is in the Universe's reference at (0,0,0) looking along the X axis. The reason is that we already have the rotation coeficients to look at the object. The object's unit vectors supply the matrix coefficients for the object to look at (rotate) the Universe. The inverse of this matrix will allow the Universe to look at (rotate) the object. As discussed previously, the unit vectors form an Orthonormal matrix; its inverse is simply the Transpose. After the object is rotated, it is translated to its position (its position according to the Universe) and projected. More on projection later.

A consequence of using the Unit Vector method is that, whatever orientation the object is in, it will always Roll, Pitch, and Yaw according to ITS axes.
For an object with unit vectors:

$$\begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix}$$

and absolute position [XT,YT,ZT], and [X,Y,Z] a point from the object's library, and [X',Y',Z'] in the Universe's reference, The Universe looks at the object:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Ay & Az \\ Bx & By & Bz \\ Cx & Cy & Cz \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix},$$

For two ships, each with unit vectors and positions:

$$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \text{ Ship 1 Unit Vectors}$$

$(XT1,YT1,ZT1)$ Ship 1 Position

$$\begin{bmatrix} Ax2 & Bx2 & Cx2 \\ Ay2 & By2 & Cy2 \\ Az2 & Bz2 & Cz2 \end{bmatrix} \text{ Ship 2 Unit Vectors}$$

$(XT2,YT2,ZT2)$ Ship 2 Position

$$\begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \text{ Transpose (Inverse) of Ship 2 Unit Vectors}$$

(X,Y,Z) in Ship 2 library, (X',Y',Z') in Universe Reference, and (X",Y",Z") in Ship 1 Reference Universe looks at ship 2:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix}$$

Ship 1 looks at the Universe looking at Ship 2:

EQUATION 10

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X'-XT1 \\ Y'-YT1 \\ Z'-ZT1 \end{bmatrix}$$

$$= \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} - \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT1 \\ YT1 \\ ZT1 \end{bmatrix}$$

Expand:

$$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \left(\begin{bmatrix} Ax2 & Bx2 & Cx2 \\ Ay2 & By2 & Cy2 \\ Az2 & Bz2 & Cz2 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix} \right)$$

Using the Distributive Law of Matrices:

$$= \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \left(\begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \right) + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix}$$

Using the Associative Law of Matrices:

$$= \left(\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \right) \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix}$$

Substituting back into Equation 10 gives:

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \left(\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \right) \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix} - \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT1 \\ YT1 \\ ZT1 \end{bmatrix}$$

Therefore:

EQUATION 11

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \left(\left(\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \right) \right) \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT2 - XT1 \\ YT2 - YT1 \\ ZT2 - ZT1 \end{bmatrix}$$

Now let:

EQUATION 12

$$\begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} Ax2 & Bx2 & Cx2 \\ Ay2 & By2 & Cy2 \\ Az2 & Bz2 & Cz2 \end{bmatrix}$$

This matrix represents the orientation of Ship 2 according to Ship 1's frame of reference. This concatentation needs to be done only once per update of Ship 2.

Also let:

EQUATION 13

$$\begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT2 - XT1 \\ YT2 - YT1 \\ ZT2 - ZT1) \end{bmatrix}$$

(XT,YT,ZT) is merely the position of Ship 2 in Ship 1's frame of reference.

This also needs to be done only once per update of Ship 2. Therefore the transformation to be applied to Ship 2's library will be of the form:

EQUATION 14

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix}$$

Therefore, every object has six degrees of freedom, and any object may look at any other object.

SUMMARY OF TRANSFORMATION ALGORITHMS:

Define Unit Vectors: $|Px| = (Ax,Ay,Az)$

$|Py| = (Bx,By,Bz)$

$|Pz| = (Cx,Cy,Cz)$

Initialize: $Ax = By = Cz = 1.000$

$Ay = Az = Bx = Bz = Cx = Cy = 0$

If Roll:

$Ay' = Ay * COS(xa) - Az * SIN(xa)$

$Az' = Ay * SIN(xa) + Az * COS(xa)$

$By' = By * COS(xa) - Bz * SIN(xa)$

$Bz' = By * SIN(xa) + Bz * COS(xa)$

$Cy' = Cy * COS(xa) - Cz * SIN(xa)$

$Cz' = Cy * SIN(xa) + Cz * COS(xa)$

If Pitch:

$Az' = Az * COS(ya) - Ax * SIN(ya)$

$Ax' = Az * SIN(ya) + Ax * COS(ya)$

$Bz' = Bz * COS(ya) - Bx * SIN(ya)$

$Bx' = Bz * SIN(ya) + Bx * COS(ya)$

$Cz' = Cz * COS(ya) - Cx * SIN(ya)$

$Cx' = Cz * SIN(ya) + Cx * COS(ya)$

If Yaw:

$Ax' = Ax * COS(za) - Ay * SIN(za)$

$Ay' = Ax * SIN(za) + Ay * COS(za)$

$Bx' = Bx * COS(za) - By * SIN(za)$

$By' = Bx * SIN(za) + By * COS(za)$

$Cx' = Cx * COS(za) - Cy * SIN(za)$

$Cy' = Cx * SIN(xa) + Cy * COS(xa)$

-continued

SUMMARY OF TRANSFORMATION ALGORITHMS:

('za', 'ya', and 'xa' are incremental rotations.)

The resultant unit vectors form a transformation matrix. For X, Y, Z in Universe reference and X', Y', Z' in Ship's reference

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

and

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

The ship's x unit vector, the vector which according to the ship is straight ahead, transforms to (Ax,Bx,Cx). For a ship in free space, this is the acceleration vector when there is forward thrust. The sum of the accelerations determine the velocity vector and the sum of the velocity vectors determine the position vector (XT,YT,ZT). For two ships, each with unit vectors and positions:

$$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix}$$ Ship 1 Unit Vectors

(XT1,YT1,ZT1) Ship 1 Position

$$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix}$$ Ship 2 Unit Vectors

(XT2,YT2,ZT2) Ship 2 Position

Ship 1 looks at the Universe:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} X - XT \\ Y - YT \\ Z - ZT \end{bmatrix}$$

(X,Y,Z) in Universe

(X',Y',Z') in Ship 1 frame of reference

Ship 1 looks at Ship 2:

$$\begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} Ax2 & Bx2 & Cx2 \\ Ay2 & By2 & Cy2 \\ Az2 & Bz2 & Cz2 \end{bmatrix}$$

(Ship 2 orientation relative to Ship 1 orientation)

$$\begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} \cdot \begin{bmatrix} XT2 - XT1 \\ YT2 - YT1 \\ ZT2 - ZT1 \end{bmatrix}$$

(Ship 2 position in Ship 1's frame of reference)

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix}$$

(X,Y,Z) in Ship 2 library

(X',Y',Z') in Ship 1 reference

VISIBILITY AND ILLUMINATION

After a polygon is transformed, whether it is a terrain polygon or it belongs to an independently moving object such as another aircraft, the next step is to determine its illumination value, if indeed, it is visible at all.

Associated with each polygon is a vector of length 1 that is normal to the surface of the polygon. This is obtained by using the vector crossproduct between the vectors forming any two adjacent sides of the polygon. For two vectors V1=[x1,y1,z1] and V2=[x2,y2,z2] the crossproduct V1×V2 is the vector [(y1*z2−y2*z1),−(x1*z2−x2*z1),(x1*y2−x2*y1)]. The vector is then normalized by dividing it by its length. This gives it a length of 1. This calculation can be done when the data base is generated, becoming part of the data base, or it can be done during program run time. The tradeoff is between data base size and program execution time. In any event, it becomes part of the transformed data.

After the polygon and its normal are transformed to the aircraft's frame of reference, we need to calculate the angle between the polygon's normal and the vector from the base of the normal to the aircraft. This is done by taking the vector dot product. For two vectors V1=[x1,y1,z1] and V2=[x2,y2,z2], V1 dot V2=length(V1)*length(V2)*cos(a) and is calulated as (x1*x2+y1*y2+z1*z2). Therefore:

$$\cos(a) = \frac{(x1 * x2 + y1 * y2 + z1 * z2)}{\text{length}(V1) * \text{length}(V2)}$$

A cosine that is negative means that the angle is between 90 degress and 270 degrees. Since this angle is facing away from the observer it will not be visible and can be rejected and not subjected to further processing. The actual cosine value can be used to determine the brightness of the polygon for added realism.

CLIPPING

Now that the polygon has been transformed and checked for visibility it must be clipped so that it will properly fit on the screen after it is projected. Standard clipping routines are well known in the computer graphics industry. There are six clipping planes as shown in the 3D representation shown in FIG. **8***a* . The 2D top view is shown in FIG. **8***b*, and the 2D side view is shown in FIG. **8***c*. It should be noted that clipping a polygon may result in the creation of addition polygon sides which must be added to the polygon description sent to the polygon display routine.

PROJECTION

As shown in FIG. **7***a*, X' is the distance to the point along the X axis, Z' is the height of the point, Xs is the distance from the eyepoint to the screen onto which the point is to be projected, and Sy is the vertical displacement on the screen. Z'/X' and Sy/Xs form similar triangles so: Z'/X'=Sy/Xs, therefore Sy=Xs*Z'/X'. Likewise, Y'/X'=Sx/Xs so Sx=Xs*Y'/X' where Sx is the horizontal displacement on the screen. However, we still need to fit Sy and Sx to the monitor display coordinates. Suppose we have a screen that is 1024 by 1024. Each axis would be plus or minus 512 with (0,0) in the center. If we want a 90 degree field of view (plus or minus 45 degrees from the center), then when a point has Z'/X'=1 it must be put at the edge of the screen where its value is 512. Therefore Sy=512*Z'/X'. (Sy is the Screen Y-coordinate). Therefore:

Sy=K*Z'/X' Sy is the vertical coordinate on the display

Sx=K*Y'/X' Sx is the horizontal coordinate on the display

K is chosen to make the viewing angle fit the monitor coordinates. If K is varied dynamically we end up with a zoom lens effect. And if we are clever in implementing the divider, K can be performed without having to actually do a multiplication.

THE DATABASE

The data base is generated from several sources. The U.S. Geological Survey (USGS) makes available various databases, two of which are of particular interest. The first is the Digital Elevation Model data which consist of an array of regularly spaced terrain elevations. This data base is converted into a data base containing polygons (whose vertices are three-dimensional points) in order to maximize the geographic area covered by CD-ROM Data Base **105** and also to reduce the amount of run-time processing required of Computer **107**. This is possible because there are large areas of terrain that are essentially flat. Note that flat does not necessarily mean level. A sloping area is flat without being level.

The Digital Elevation Model data elevations are spaced 30 meters apart. 30 meters=30m×39.37 in/m×1 ft/12 in=98.245 ft. A linear mile contains 5,280 ft/mi×1 data point/98.245 ft=53.65 data points/mi. Therefore, a square mile contains 53.65×53.65=2878 data points. California has a total area of 158,706 square miles which requires 158,706×2878=456,755,868 data points. Since this figure includes 2,407 sq mi of inland water areas, there are 2407×2878=6,927,346 data points just for inland water. The U.S. has a total area of 3,618,773 square miles which requires 3,618,773×2878=10,414,828,694 data points. This figure includes 79,484 sq mi of inland water areas requiring 79,484×2878=228,754,952 data points just for inland water.

The polygon data are organized in geographic data blocks. Because the amount of data in each geographic data block depends on the number of polygons and because the number of polygons depends on the flatness of the terrain, the size of each geographic data block is variable. Therefore, an address table is maintained that contains a pointer to each geographic data block. The first choice is to decide on the geographic area represented by the block. For the present invention the size is 20 mi×20 mi=400 sq mi. Therefore, the polygon data base for California requires 158,706 sq mi×1 block/400 sq mi=397 geographic data blocks. The number of polygons in a given geographic data block depends on the flatness of the terrain and what we decide is 'flat'. The definition of 'flatness' is that for a polygon whose vertices are three-dimensional points, there will be no elevation points that are higher than the plane of the polygon and there will be no elevation points that are below the the plane of the polygon by a distance called the Error Factor. A small Error Factor will require more polygons to represent a given terrain than will a large Error Factor. A small Error Factor will also generate the terrain more accurately. The Error Factor does not have to be the same for all Geographic Data Blocks. Blocks for areas of high interest, like airports and surrounding areas can be generated using a small Error Factor in order to represent the terrain more precisely. The present invention uses an Error Factor of 10 ft for areas surrounding airports and 50 ft for all other areas.

A procedure for generating the polygon data base from the Digital Elevation Model data is demonstrated in FIG. **12***a* through FIG. **12***f* and FIG. **13***a* through FIG. **13***f*. We start with three points which define a polygon and which has a surface. We select the next elevation point and decide if it belongs in the polygon accordinng to the citeria previously discussed. If it does, it gets added to the polygon. If not, not. We then test additional adjacent points until we run out. Then we start over with another three points.

When we are done generating polygons for a Geographic Data Block we go back and examine them; any polygon that is 'too big' is broken down into smaller polygons. This is to make sure there are always enough polygons on the screen to provide a proper reference for the pilot. (A single large polygon on the screen would not have any apparent motion.) Finally, the polygons are assigned colors and/or shades so that adjacent polygons will not blend into each other.

The other USGS data base used is the Digital Line Graph data which includes: political and administrative boundaries; hydrography consisting of all flowing water, standing water, and wetlands; major transportation systems consisting of roads and trails, railroads, pipelines, transmission lines, and airports; and significant manmade structures. The Digital Line Graph data is two-dimensional. In the present invention features such as water, roads, railroads, and pipelines are represented as polygons with elevations determined from the Digital Elevation Model data. Transmission lines and significant manmade structures are defined as three-dimensional objects made of polygons and are placed according to the elevations determined from the Digital Elevation Model data. The different types of objects are tagged so that by using Control Panel **106** the pilot can select them to be highlighted by category or by specific object. For example, the pilot can choose to have all airports highlighted or just the destination airport. The pilot can also choose to have a specific highway highlighted.

Data from additional digital data bases can also be incorporated. An example of such a data base is from Jeppesen Sanderson whose NavData Services division provides aeronautical charts and makes this information available in digital form.

While preferred embodiments of the present invention have been shown, it is to be expressly understood that modifications and changes may be made thereto and that the present invention is set forth in the following claims.

I claim:

1. A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system for locating said aircraft's position in three dimensions;

a digital data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one polygon, said terrain data generated from elevation data of said real terrestrial terrain;

an attitude determining system for determining said aircraft's orientation in three dimensional space;

a computer to access said terrain data according to said aircraft's position and to transform said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and

a display for displaying said three dimensional projected image data.

2. The pilot aid of claim **1**, wherein said position determining system comprises a standard system for receiving and processing data from the global positioning system.

3. The pilot aid of claim **1**, wherein said attitude determining system comprises a standard avionics system.

4. The pilot aid of claim **1**, wherein said digital data base comprises a cd rom disc and cd rom drive.

5. The pilot aid of claim **1**, further comprising a control panel to select at least one operating feature.

6. The pilot aid of claim **5**, wherein said at least one operating feature comprises at least one feature selected from a group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, and providing a three dimensional projected image of a route ahead.

7. The pilot aid as described in claim **1** wherein said digital data base further comprises structure data, said structure data representing manmade structures as one or more polygons.

8. The pilot aid as described in claim **1** wherein said elevation data comprises an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by said at least one polygon each elevation point within each said polygon is within a first distance of said plane of each said polygon.

9. The pilot aid as described in claim **8** wherein in a second region of said terrain represented by said at least one polygon each elevation point within each said polygon is within a second distance of said plane of each said polygon in said second region, said second distance different from said first distance.

10. The pilot aid as described in claim **9** wherein no elevation point within each said polygon in said first region and said second region is above said plane of said polygon.

11. The pilot aid as described in claim **8** wherein no elevation point within each said polygon in said first region is above said plane of said polygon.

12. A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system for locating said aircraft's position in three dimensions;

a digital data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one polygon, said terrain data generated from elevation data of said real terrestrial terrain;

an attitude determining system for determining said aircraft's orientation in three dimensional space;

a computer to access said terrain data according to said aircraft's position and to transform said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and

a mass storage memory for recording said aircraft position data and said aircraft's attitude data for allowing a flight of said aircraft over said terrain to be displayed at a later time.

13. The pilot aid of claim **12**, wherein said position determining system comprises a standard system for receiving and processing data from the global positioning system.

14. The pilot aid of claim **12**, wherein said attitude determining systems comprises a standard avionics system.

15. The pilot aid of claim **12**, wherein said digital data base comprises a cd rom and a cd rom drive.

16. The pilot aid of claim **12**, further comprising a control panel to select at least one operating feature.

17. The pilot aid of claim **16**, wherein said at least one operating feature comprises at least one feature selected from a group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, providing a three dimensional projected image of a route ahead, and providing a three dimensional projected image of a previous flight.

18. The pilot aid as described in claim **12** wherein said digital data base further comprises structure data, said structure data representing manmade structures as one or more polygons.

19. The pilot aid as described in claim 12 wherein said elevation data comprises an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by said at least one polygon each elevation point within each said polygon is within a first distance of said plane of each said polygon.

20. The pilot aid as described in claim 19 wherein in a second region of said terrain represented by said at least one polygon each elevation point within each said polygon is within a second distance of said plane of each said polygon in said second region, said second distance different from said first distance.

21. The pilot aid as described in claim 20 wherein no elevation point within each said polygon in said first region and said second region is above said plane of said polygon.

22. The pilot aid as described in claim 19 wherein no elevation point within each said polygon in said first region is above said plane of said polygon.

23. A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

- a position determining system for locating said aircraft's position in three dimensions;
- a digital data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one polygon, said terrain data generated from elevation data of said real terrestrial terrain;
- a first attitude determining system for determining said aircraft's orientation in three dimensional space;
- a head mounted display worn by said pilot of said aircraft;
- a second attitude determining system for determining the orientation of said pilot's head in three dimensional space; and
- a computer to access said terrain data according to said aircraft's position and to transform said terrain data to provide three dimensional projected image data to said head mounted display according to said aircraft's orientation and said pilot head orientation.

24. The pilot aid as described in claim 23 wherein said digital data base further comprises structure data, said structure data representing manmade structures as one or more polygons.

25. The pilot aid as described in claim 23 wherein said elevation data comprises an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by said at least one polygon each elevation point within each said polygon is within a first distance of said plane of each said polygon.

26. The pilot aid as described in claim 25 wherein in a second region of said terrain represented by said at least one polygon each elevation point within each said polygon is within a second distance of said plane of each said polygon in said second region, said second distance different from said first distance.

27. The pilot aid as described in claim 26 wherein no elevation point within each said polygon in said first region and said second region is above said plane of said polygon.

28. The pilot aid as described in claim 25 wherein no elevation point within each said polygon in said first region is above said plane of said polygon.

29. A method of using an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

- locating said aircraft's position in three dimensions;
- providing a data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one polygons, said terrain data generated from elevation data of said real terrestrial terrain;
- determining said aircraft's orientation in three dimensional space;
- accessing said terrain data according to said aircraft's position;
- transforming said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and
- displaying said three dimensional projected image data.

30. The method of claim 29 further comprising selecting at least one operating feature, wherein said at least one operating feature comprises at least one feature selected from a group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, and presenting a three dimensional projected image of a route ahead.

31. The method as described in claim 29 wherein said terrain data base is produced by a method comprising the steps of:

- providing a plurality of elevation points, each of said plurality of elevation points representing an elevation of a point on a terrain;
- defining a polygon having at least one vertex defined by at least one of said elevation points;
- examining an adjacent one of said plurality of elevation points to determine if expanding said polygon to an expanded polygon to include said adjacent one of said plurality of elevation points causes at least one of said plurality of elevation points within said expanded polygon not to be within a first distance of a plane of said expanded polygon; and
- expanding said polygon to include said adjacent one of said plurality of elevation points if each of said elevation points within said expanded polygon is within said first distance of said plane.

32. The method as described in claim 31 wherein at least one additional adjacent one of said plurality of elevation points is examined, and wherein said polygon is expanded to include said at least one additional one of said plurality of elevation points that does not cause any of said elevation points within said expanded polygon not to be within said first distance of said plane of said expanded polygon.

33. The method as described in claim 32 wherein said polygon is stored in said terrain data base after all of said elevation points adjacent to said polygon have been examined.

34. The method as described in claim 32 wherein additional polygons are defined, expanded, and added to said terrain database.

35. The method as described in claim 31 wherein at least one additional adjacent one of said plurality of elevation points is examined, and wherein said polygon is expanded to include said at least one additional one of said plurality of elevation points that does not cause any of said elevation points within said expanded polygon to be above said plane of said expanded polygon and does not cause any of said elevation points within said expanded polygon not to be within said first distance of said plane of said expanded polygon.

36. The method as described in claim **35** wherein said polygon is stored in said terrain data base after all of said elevation points adjacent to said polygon have been examined.

37. The method as described in claim **31** wherein said adjacent one of said plurality of elevation points is further examined to determine if at least one of said plurality of elevation points within said expanded polygon is above said plane of said expanded polygon, and said polygon is expanded if none of said elevation points within said expanded polygon is above said plane of said expanded polygon and if each of said elevation points within said expanded polygon is within said first distance of said plane.

* * * * *

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3570 PLEASANT ECHO DRIVE
SAN JOSE CA 95148-1916

ART UNIT	PAPER NUMBER
2304	6

DATE MAILED: 05/09/95

This is a communication from the examiner in charge of your application.
COMMISSIONER OF PATENTS AND TRADEMARKS

☐ This application has been examined ☒ Responsive to communication filed on 02/13/95 ☒ This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), 0 days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. ☒ Notice of References Cited by Examiner, PTO-892.
2. ☐ Notice of Draftsman's Patent Drawing Review, PTO-948.
3. ☐ Notice of Art Cited by Applicant, PTO-1449.
4. ☐ Notice of Informal Patent Application, PTO-152.
5. ☐ Information on How to Effect Drawing Changes, PTO-1474.
6. ☐ ______

Part II SUMMARY OF ACTION

1. ☒ Claims 1-39 are pending in the application.
   Of the above, claims 29-30 are withdrawn from consideration.
2. ☐ Claims ______ have been cancelled.
3. ☐ Claims ______ are allowed.
4. ☒ Claims 1-28 and 31-39 are rejected.
5. ☐ Claims ______ are objected to.
6. ☐ Claims ______ are subject to restriction or election requirement.
7. ☐ This application has been filed with informal drawings under 37 C.F.R. 1.85 which are acceptable for examination purposes.
8. ☐ Formal drawings are required in response to this Office action.
9. ☐ The corrected or substitute drawings have been received on ______. Under 37 C.F.R. 1.84 these drawings are ☐ acceptable; ☐ not acceptable (see explanation or Notice of Draftsman's Patent Drawing Review, PTO-948).
10. ☐ The proposed additional or substitute sheet(s) of drawings, filed on ______, has (have) been ☐ approved by the examiner; ☐ disapproved by the examiner (see explanation).
11. ☐ The proposed drawing correction, filed ______, has been ☐ approved; ☐ disapproved (see explanation).
12. ☐ Acknowledgement is made of the claim for priority under 35 U.S.C. 119. The certified copy has ☐ been received ☐ not been received ☐ been filed in parent application, serial no. ______; filed on ______.
13. ☐ Since this application apppears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. ☐ Other

01193

EXAMINER'S ACTION

PTOL-326 (Rev. 2/93)

Part III DETAILED ACTION

Notice to Applicants

1. This office action is responsive to the preliminary amendment filed on October 20, 1995. As per request, the amendment mailed on July 10, 1995 of the parent application, serial number 08/274,394 which was abandoned on October 16, 1995, has been enter.

2. In the amendment filed on July 10, 1995, claims 1, 5-7, 11-13, 17-22, 31-32, 36-39 have been amended. Claims 29-30 have been canceled. Thus, claims 1-28 and 31-39 are pending.

3. The rejections under 35 U.S.C. § 112, second paragraph, have been withdrawn upon the amended claims.

Claim Rejections - 35 USC § 103

4. The following is a quotation of 35 U.S.C. § 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.
>
> Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this

on the merits. Accordingly, claims 29-30 are withdrawn from consideration as being directed to a non-elected invention. See 37 C.F.R. § 1.142(b) and M.P.E.P. § 821.03.

Claim Rejections - 35 USC § 112

4. Claim 1-28 and 31-39 are rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

4.1. As per claim 1 (as exemplary of claims 1, 7 and 13), line 7, the phrase "one or more" is vague and indefinite. The word "and" should be added after the phrase "to said aircraft's orientation" on line 17.

4.2. As per claim 5 (as exemplary of claims 5 and 11), line 2, the phrase "one or more operating features" is unclear since they are not defined properly.

4.3. As per claim 6 (as exemplary of claims 6, 12 and 37), the phrases "said one or more operating features" and "the group" on lies 2 and 3, respectively, have no antecedent basis.

4.4. As per newly added claim 17 (as exemplary of claims 17-19), the instant passage on lines 3-6 is unclear as to what the first region of terrain represented. Verification is requested. Furthermore, the phrases "one or more" and "distance or more" on lines 5 and 6, respectively, are vague and indefinite.

4.5. As per newly added claim 20 (as exemplary of claims 20-22), similar to the above, it is unclear as to what the second region represented. Moreover, the phrases "one or more" and "distance or more" on lines 2 and 4, respectively, are vague and indefinite.

4.6. As per newly added claims 23 and 26 (as exemplary of claims 23-28), it is unclear as to what the no elevation point means. Clarification is requested.

4.7. As per newly added claim 36, the comma at the end of line 10 should be deleted.

4.8. As per newly added claim 38, lines 5-6, the phrase "one or more vertices defined by one or more of said elevation points" is vague and indefinite. Furthermore, the instant passage on lines 7-14 is unclear as to how to examining an adjacent one of the plurality and how to expanding the polygon to include the adjacent one of the plurality of elevation points. Verification is requested. Moreover (as exemplary of claims 38 and 39), the phrases "one or more" and "distance or more" on lines 9 and 14, respectively, are vague and indefinite.

4.9. The remaining claims, not specifically mentioned, are rejected for incorporating the defects from their respective parent by dependency.

5. The following rejections are based on the examiner's best interpretation of the claims in light of the 35 U.S.C. 112 errors noted above.

Claim Rejections - 35 USC § 103

6. The following is a quotation of 35 U.S.C. § 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.
>
> Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the invention was made, owned by the same person or subject to an obligation of assignment to the same person.

7. Claims 1-12 are rejected under 35 U.S.C. § 103 as being unpatentable over Beckwith et al (4,660,157) in view of Behensky et al. (5,005,148) or a brochure from Atari Game Corp. (Hard Driving') or a brochure from Atari Game Corp. (Steel Talons).

7.1. With respect to claims 1, 5-7, 11-12, 14 and 36-37, Beckwith et al. discloses a digital system for producing a real time video display in perspective of terrain over which an aircraft is passing on the basis of compressed digital data stored on a cassette tape (see at least an abstract). Beckwith et al. discloses that the system includes a position determining means for locating the aircraft's position in three dimensions and an attitude determining means for determining the aircraft's orientation in three dimensional space (see at least figure 1 and columns 5 and 6). Beckwith et al. further discloses that the system includes a digital data base means for storing a compressed terrain data (see at least the abstract). Beckwith et al. also discloses a computer means for reading compressed terrain data from the digital data base means in a controlled manner based on the instantaneous geographical of the aircraft as provided by the aircraft navigation computer system, reconstructing the compressed data by suitable processing and writing the reconstructed data into a scene memory, and then providing a 3D perspective on the display (see at least columns 2 and 3).

Beckwith et al. does not explicitly disclose that a digital data base means containing polygon data representing terrain and manmade structures. However, Behensky et al. suggests a driving simulator for a video game which includes the road and other terrain are produced by mathematically transforming a three-dimensional polygon data base (see at least column 2, lines 33-38). The suggestion of Behensky et al. in at least column 2 would have motivated one of ordinary skill in the art to combine with the system of Beckwith et al. in order to provide a significant reduction of data base storage and a larger geographic areas can be stored so that it is not necessary to generate a data base of each mission. Similarly, the digital data base means containing polygon data representing terrain and manmade structures is also taught in a brochure from Atari Game Corp. (Hard Driving') or a brochure from Atari Game Corp. (Steel Talons). Thus, because of the motivation set forth above, it would have been obvious to a person of ordinary skill in the art at the time the invention was made to combine the teachings of Behensky et al. or the brochure from Atari Game Corp. (Hard Driving') or the brochure from Atari Game Corp. (Steel Talons) with the system of Beckwith et al.

7.2. With respect to claims 2-3 and 8-9, Beckwith et al. discloses the claimed invention as discussed above but does not explicitly discloses that the position determining means comprises a standard system for retrieving and processing data from the global positioning system and the attitude determining means comprises a standard avionics systems. However, the use of the standard system for retrieving and processing data from global positioning system and the standard avionics systems are well known effective and efficient means for determining the position and the orientation of the aircraft. For examples, the Maher patent (4,485,383) shows a receiver for receiving global positioning system and the Timothy patent shows a method for determining the orientation of a moving object form a single GPS receiver and producing roll, pitch, and yaw information. It would have been obvious to one of ordinary skill in the art at the time of the invention to utilize the global positioning system and the standard avionics system in such a system as taught through Beckwith et al. because it would produce high degree of accuracy in determining the position and orientation of the aircraft including roll, pitch, and yaw information.

7.3. With respect to claims 4 and 10, Beckwith et al. does not specifically disclose that the digital data base means comprises a CD rom disc and CD rom drive. However, the use of CD rom disc and CD rom drive for storing data is well known effective and efficient means for storing any data. It would have been obvious to one of ordinary skill in the art at the time of the invention to utilize CD rom disc and CD rom drive in such a system as taught through Beckwith et al. because it would permit high degree of accuracy in the storing and restoring data, random access to the data so that the requirements for cache storage are reduced.

8. Claim 13 is rejected under 35 U.S.C. § 103 as being unpatentable over Beckwith et al and Behensky et al. as applied to claims 1-12 above, and further in view of the sales brochure from the Polhemus company.

Beckwith et al. and Behenský et al. disclose the claimed invention except for a head mounted display means worn by the pilot and an attitude determining means for determining the orientation of the pilot's head in three dimensional space. However, the sales brochure from the Polhemus company suggests the commercial available of a position and orientation sensor which can be used on a head-mounted display. The suggestion of the Polhemus company would have motivated one of ordinary skill in the art to combine the teaching of Polhemus company with the system of Beckwith et al. in order to allow the pilot to have a complete range of motion to receive a synthesized view of the world, a complete unhindered by the aircraft structure. Thus, because of the motivation set forth above, it would have been obvious to a person of ordinary skill in the art at the time the invention was made to combine the teachings in Polhemus's brochure and Beckwith et al. patent.

9. In view of the indefinite state(s) of the claimed invention, no prior art has been applied against the claims 17-28, 31-35 and 38-39. However, applicants are requested to consider the cited references below fully when responding to the office action.

10. All claims are rejected.

11. The following references are cited as being of general interest: Sullivan et al. (4,213,252), Heartz (4,715,005), Dawson et al. (5,179,638) and Nack et al. (5,317,689).

Remarks

12. Applicant's arguments filed on February 13, 1995 have been fully considered but they are not deemed to be persuasive.

13. On page 16, second paragraph, the applicants argue that claims 1-12 are patentable over Beckwith et al. and Behensky et al. because there is no teaching or suggestion to combine the references. It is not necessary that the references actually suggest, expressly or in so many words, the changes or improvements that applicant has made. The test for combining references is what the references as a whole would have suggested to one of ordinary skill in the art. In re Shecler, 168 USPQ 716 (CCPA 1971); In re McLaughlin, 170 USPQ 209 (CCPA 1971); In re Young, 159 USPQ 725 (CCPA 1986).

The Examiner recognizes that references cannot be arbitrarily combined and that there must be some logical reason why one skill in the art would be motivated to make the proposed combination of references. In re Regel 188 USPQ 136 (CCPA 1975). However, there is no requirement that the motivation to make the combination be expressly articulated in one or more of the references; the teaching, suggestion or inference can be found not only in the references but also from knowledge generally available to one of ordinary skill in the art. Ashland Oil v. Delta Resins 227 USPQ 657 (CAFC 1985). The test for combining references is what the combination of disclosures taken as a whole would suggest to one of ordinary skill in the art. In McLaughlin 170 USPQ 209 (CCPA 1971); In re Rosselet 146 USPQ 183 (CCPA 196). References are evaluated by what they collectively suggest to one versed in the art, rather than by their specific disclosures. In Re Simon, 174 USPQ 114 (CCPA 1972); In Re Richman 165 USPQ 509, 514 (CCPA 1970).

14. On page 16, third paragraph, the applicants argue that the polygon of Behensky et al. do not represent real terrain in any manner, but rather are, instead, essentially "building blocks" which may be accessed from the data base to create the fictional scene through which the drive is driving. This limitation is not found in the claims. The only recitation is that "data base comprising terrain data, said terrain data representing as one or more polygons". Therefore, the building blocks as taught in Behensky et al. still are considered as the terrain data. Therefore, the rejection under 35 U.S.C. § 103 is considered to be proper.

In addition, the digital data base which comprises terrain data representing as at least one of polygons is well known in the art at the time the invention was made (see at least U.S. patent number 5,192,208 issued to Ferguson et al., for example).

15. On page 17, second paragraph, the applicants argue that there is no teaching of constructing polygon based on an array of elevation points. This limitation is not found in the claims. Claimed subject matter not the specification, is the measure of invention. Disclosure contained in the specification can not be read into the claims for the purpose of avoiding the prior art. In re Sporck, 55 CCPA 743, 386 F.2d 924, 155 USPQ 687 (1986); In re Self, 213 USPQ 1,5 (CCPA 1982); In re Priest, 199 USPQ 11,15 (CCPA 1978).

16. Applicant's amendment necessitated the new grounds of rejection. Accordingly, **THIS ACTION IS MADE FINAL.** See M.P.E.P. § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 C.F.R. § 1.136(a).

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS FINAL ACTION IS SET TO EXPIRE THREE MONTHS FROM THE DATE OF THIS ACTION. IN THE EVENT A FIRST RESPONSE IS FILED WITHIN TWO MONTHS OF THE MAILING DATE OF THIS FINAL ACTION AND THE ADVISORY ACTION IS NOT MAILED UNTIL AFTER THE END OF THE THREE-MONTH SHORTENED STATUTORY PERIOD, THEN THE SHORTENED STATUTORY PERIOD WILL EXPIRE ON THE DATE THE ADVISORY ACTION IS MAILED, AND ANY EXTENSION FEE PURSUANT TO 37 C.F.R. § 1.136(a) WILL BE CALCULATED FROM THE MAILING DATE OF THE ADVISORY ACTION. IN NO EVENT WILL THE STATUTORY PERIOD FOR RESPONSE EXPIRE LATER THAN SIX MONTHS FROM THE DATE OF THIS FINAL ACTION.

17. Any inquiry concerning this communication or earlier communications from the examiner should be directed to examiner Tan Nguyen, whose telephone number is (703) 305-9755. The examiner can normally be reached on Monday-Thursday from 7:30 AM-6:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Kevin J. Teska, can be reached on (703) 305-9704. The fax phone number for this Group is (703) 305-9564.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 305-3800.

TN

TAN NGUYEN
May 04, 1995

KEVIN J. TESKA
SUPERVISORY PATENT EXAMINER
GROUP 2300

TO SEPARATE, HOLD TOP AND BOTTOM EDGES, SNAP—APART AND DISCARD CARBON

FORM PTO-892 (REV. 2-92) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	SERIAL NO.	GROUP ART UNIT	ATTACHMENT TO PAPER NUMBER
NOTICE OF REFERENCES CITED	~~08/274,394~~ 08-513,298	2304	6
	APPLICANT(S): MARGOLIN		

U.S. PATENT DOCUMENTS

•		DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
	A	4213252	07/80	SULLIVAN ET AL.	395 ~~364~~	125	
	B	4715005	12/87	HEART	395 ~~364~~	125 ~~521~~	
	C	5179638	01/93	DAWSON ET AL.	395	125	
	D	5317689	05/94	NACK ET AL.	395	163	
	E						
	F						
	G						
	H						
	I						
	J						
	K						

FOREIGN PATENT DOCUMENTS

•		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PERTINENT PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

R

S

T

U

EXAMINER	DATE
Jan Nguyen	05/04/95

* A copy of this reference is not being furnished with this office action.
(See Manual of Patent Examining Procedure, section 707.05 (a).)

01206

08/274,394

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKETT NO.
08/274,394	07/11/94	MARGOLIN	J

B3M1/0707

JED MARGOLIN
3570 PLEASANT ECHO DRIVE
SAN JOSE CA 95148-1916

NGUYEN, T EXAMINER

ART UNIT	PAPER NUMBER
2304	7

DATE MAILED: 07/07/95

EXAMINER INTERVIEW SUMMARY RECORD

All participants (applicant, applicant's representative, PTO personnel):

(1) KEITH G. ASKOFF (3)

(2) TAN NGUYEN (4)

Date of Interview 07/06/95

Type: ☒ Telephonic ☐ Personal (copy is given to ☐ applicant ☒ applicant's representative).

Exhibit shown or demonstration conducted: ☐ Yes ☒ No. If yes, brief description:

Agreement ☒ was reached with respect to some or all of the claims in question. ☐ was not reached.

Claims discussed: 1-39

Identification of prior art discussed: Beckwith et al. (4,660,157), Behensky et al. (5,005,148)

Description of the general nature of what was agreed to if an agreement was reached, or any other comments: The rejections under 35 U.S.C. 112, second paragraph have been discussed. Applicant's representative agreed to amend the claims to overcome the 112's problems and the art rejections. Examiner agreed to reconsider the application upon the discussion and the formal amendment after final.

(A fuller description, if necessary, and a copy of the amendments, if available, which the examiner agreed would render the claims allowable must be attached. Also, where no copy of the amendments which would render the claims allowable is available, a summary thereof must be attached.)

☒ 1. It is not necessary for applicant to provide a separate record of the substance of the interview.

Unless the paragraph below has been checked to indicate to the contrary, A FORMAL WRITTEN RESPONSE TO THE LAST OFFICE ACTION IS NOT WAIVED AND MUST INCLUDE THE SUBSTANCE OF THE INTERVIEW (e.g., items 1-7 on the reverse side of this form). If a response to the last Office action has already been filed, then applicant is given one month from this interview date to provide a statement of the substance of the interview.

☐ 2. Since the examiner's interview summary above (including any attachments) reflects a complete response to each of the objections, rejections and requirements that may be present in the last Office action, and since the claims are now allowable, this completed form is considered to fulfill the response requirements of the last Office action. Applicant is not relieved from providing a separate record of the substance of the interview unless box 1 above is also checked.

Tan Nguyen
Examiner's Signature

PTOL-413 (REV. 2-93)

ORIGINAL FOR INSERTION IN RIGHT HAND FLAP OF FILE WRAPPER

01207

0402055.P002

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

DO NOT ENTER
TN 08/02/95

In re Application of:	)	
Jed Margolin	)	
Serial No.: 08/274,394	)	Examiner: T. Nguyen
Filed: July 11, 1994	)	Art Unit: 2304
For: PILOT AID USING SYNTHETIC REALITY	)	

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

AMENDMENT AND RESPONSE

Dear Sir:

In response to the Office Action of May 9, 1995, please enter the following amendments and consider the following remarks.

IN THE CLAIMS

Please delete claims 29 - 30, without prejudice.

Please amend the following claims.

1. (Twice Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system for locating said aircraft's position in three dimensions;

For the foregoing reasons, Applicant submits that all objections and rejections have been overcome. Applicant submits that all pending claims are in condition for allowance and allowance of the same is respectfully requested.

Respectfully submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: July 10, 1995

Keith G. Askoff
Reg. No. 33,828

12400 Wilshire Boulevard
Seventh Floor
Los Angeles, California 90025
(408) 720-8598

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage in an envelope addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231

on July 10, 1995
Date of Deposit

Carolyn C. Caires
Name of Person Mailing Correspondence

Carolyn C. Caires — Signature

7/10/95 — Date

01209

002055.P002

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Jed Margolin

Serial No.: 08/274,394

Filed: July 11, 1994

For: PILOT AID USING SYNTHETIC REALITY

Examiner: T. Nguyen

Art Unit: 2304

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

CHANGE OF ADDRESS UNDER 37 C.F.R. § 1.33(d)

Dear Sir:

Pursuant to 37 C.F.R. § 1.33(d) Applicant hereby changes Applicant's correspondence address as follows:

Keith G. Askoff
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN
12400 Wilshire Boulevard, 7th Floor
Los Angeles, CA 90025
(408) 720-8598

Please address all future communications to the above address.

Respectfully submitted,

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: July 10, 1995

Keith G. Askoff
Reg. No. 33,828
12400 Wilshire Boulevard
Seventh Floor
Los Angeles, California 90025
(408) 720-8598

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage in an envelope addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231

on July 10, 1995.
Date of Deposit

Carolyn C. Caires
Name of Person Mailing Correspondence

Signature 7/10/95
Date

01211

08/274,394

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
08/274,394	07/11/94	MARGOLIN	J

B3M1/0803

KEITH G. ASKOFF
BLAKELY, SOKOLOFF, TAYLOR AND ZAFMAN
12400 WILSHIRE BOULEVARD, 7TH FLOOR
LOS ANGELES, CA 90025

EXAMINER	
NGUYEN, T	
ART UNIT	PAPER NUMBER
2304	10

DATE MAILED: 08/03/95

Below is a communication from the EXAMINER in charge of this application

COMMISSIONER OF PATENTS AND TRADEMARKS

ADVISORY ACTION

☒ THE PERIOD FOR RESPONSE:

a) ☒ is extended to run ______ or continues to run 3.0 months from the date of the final rejection

b) ☒ expires three months from the date of the final rejection or as of the mailing date of this Advisory Action, whichever is later. In no event however, will the statutory period for the response expire later than six months from the date of the final rejection.

Any extension of time must be obtained by filing a petition under 37 CFR 1.136(a), the proposed response and the appropriate fee. The date on which the response, the petition, and the fee have been filed is the date of the response and also the date for the purposes of determining the period of extension and the corresponding amount of the fee. Any extension fee pursuant to 37 CFR 1.17 will be calculated from the date of the originally set shortened statutory period for response or as set forth in b) above.

☐ Appellant's Brief is due in accordance with 37 CFR 1.192(a).

☒ Applicant's response to the final rejection, filed 07/14/95 has been considered with the following effect, but it is not deemed to place the application in condition for allowance:

1. ☒ The proposed amendments to the claim and /or specification will not be entered and the final rejection stands because:

a. ☐ There is no convincing showing under 37 CFR 1.116(b) why the proposed amendment is necessary and was not earlier presented.

b. ☒ They raise new issues that would require further consideration and/or search. (See Note).

c. ☐ They raise the issue of new matter. (See Note).

d. ☐ They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal.

e. ☐ They present additional claims without cancelling a corresponding number of finally rejected claims.

NOTE: the significant amendment raises new issue (see lines 6-8 of claims 1, 7, 13 and lines 6-7 of claim 36) that would require further consideration and search.

2. ☐ Newly proposed or amended claims ______ would be allowed if submitted in a separately filed amendment cancelling the non-allowable claims.

3. ☒ Upon the filing an appeal, the proposed amendment ☐ will be entered ☒ will not be entered and the status of the claims will be as follows:

Claims allowed: ______
Claims ~~objected~~ withdrawn to: 29 - 30
Claims rejected: 1-28 and 31-39

However;

☐ Applicant's response has overcome the following rejection(s): ______

4. ☐ The affidavit, exhibit or request for reconsideration has been considered but does not overcome the rejection because ______

5. ☐ The affidavit or exhibit will not be considered because applicant has not shown good and sufficent reasons why it was not earlier presented.

☐ The proposed drawing correction ☐ has ☐ has not been approved by the examiner.

☐ Other

KEVIN J. TESKA
SUPERVISORY PATENT EXAMINER
GROUP 2300

01212

PTOL-303 (REV. 5-89)

PTO-103c (rev. 6-79)
SECURITY FILE

GROUP NO.	FILING DATE	SERIAL NO. (SERIES OF 1979)
AUG 29 94 07		274,394 — 11 JUL 94

08/274,394

#A 11

SCREENED BY	
LICENSE	☐
DATE	
DARCOM	☐
NAVY	☐
AF	☐
CE	☐
DOE	☐
NASA	☐
NSA	☐
______	☐

APPLICANT	INVENTION

DRAWINGS	TOTAL CL'S	IND CL'S	FILING FEE REC	TRANSACTION	ATT'Y DK.

CLEARED BY
GROUP 220, SECURITY

RECOMMENDATION BY EXPERTS

(Every expert examining this application should indicate an express RECOMMENDATION followed by their SIGNATURE, AGENCY AND DATE)

Could not find anything here that could not be deduced from a Graphics 101 book. However, the AF would have a definite interest in the material.

Peter D Ruth
WL/FIGP-1, 513-255-8252

No secrecy recommended, M. Gordon, AFLSA/JACRP, 3 Jan 95

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
DARCOM	NAVY	AF	CE	DOE	NASA	NSA	LOG	185	OTHER	SCREENED BY

PTO-1453 (12-80)

01213

PTO-103c (rev. 6-79) SECURITY FILE			
	GR. NO	FILING DATE	271 394 SERIAL NO. (SERIES OF 1970)
			11 JUL 94
SCREENED BY	AUG - 4 9407		
LICENSE ☐	APPLICANT		INVENTION
DATE			
DARCOM ☐ NAVY ☐ AF ☑ CE ☐ DOE ☐ NASA ☐ NSA ☐ _______ ☐	DRAWINGS / TOTAL CL'S / IND CL'S / FILING FEE REC / TRANSACTION / ATT'Y DK.		

ACCESS ACKNOWLEDGEMENT

As Required by

Title 35, United States Code (1952) Section 181

I hereby acknowledge that I have inspected the disclosure of the above identified application for patent in the administration of the law cited above, on behalf of the department or agency which I represent, and promise that any information acquired from said application will not be divulged, disclosed or used for any purpose other than in the administration of the cited law.

NAME	DATE	AGENCY REPRESENTED
J. Brahi	9/23/94	SACP
[illegible]	10/3/94	WL/AA
Peter Sp[illegible]	20 Nov 94	WL/FIGP-1
M Jordan	3 Jan 95	AFLSA/JACMP

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a digital data base [means containing polygon] comprising terrain data, said terrain data representing terrain as one or more polygons [and manmade structures];

an attitude determining system [means] for determining said aircraft's orientation in three dimensional space;

[a control panel means for allowing said pilot to select different operating features;]

a computer [means for using said aircraft position data] to access said terrain data according to said aircraft's position and [manmade structure data from said digital data base and using said aircraft orientation data] to transform said terrain [and manmade structure] data to provide three dimensional projected image data according to said aircraft's orientation [operating features selected by said pilot];

[a display means for displaying said three dimensional projected image data;]

a mass storage memory for recording said aircraft position data and said aircraft's attitude data for allowing [said aircraft's] a flight of said aircraft over said terrain to be displayed at a later time.

13 8. (Once Amended) The pilot aid [position determining means] of claim 12 7, wherein said position determining system [means] comprises a standard system for receiving and processing data from the global positioning system.

14 9. (Once Amended) The pilot aid [attitude determining means] of claim 12 7, wherein said attitude determining systems [means] comprises a standard avionics system.

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15 10. (Once Amended) The pilot aid [digital data base] of claim 7 12, wherein said digital data base [means] comprises a cd rom and a cd rom drive.

11. (Once Amended) The pilot aid [control panel means] of claim 7, further comprising a control panel to select one or more operating features [wherein said control panel means selects the functions of pan, tilt, and zoom].

12. (Once Amended) The pilot aid [control panel means] of claim 11 [7], wherein said one or more operating features comprise one or more features selected from the group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, providing a three dimensional projected image of a route ahead, and providing a three dimensional projected image of a previous flight [control panel means permits said pilot to preview the route ahead or to review previous flights].

13. (Once Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system [means] for locating said aircraft's position in three dimensions;

a digital data base [means containing polygon] comprising terrain data, said terrain data representing terrain as one or more polygons [and manmade structures];

[an] a first attitude determining system [means] for determining said aircraft's orientation in three dimensional space;

a head mounted display [means] worn by said pilot of said aircraft;

[an] a second attitude determining system [means] for determining the orientation of said pilot's head in three dimensional space;

[a control panel means for allowing said pilot to select different operating features;]

a computer [means for using said aircraft position data] to access said terrain data according to said aircraft's position and [manmade structure data from said digital data base and using said aircraft orientation data and said pilot head orientation data] to transform said terrain [and manmade structure] data to provide three dimensional projected image data to said head mounted display according to said aircraft's orientation and said pilot head orientation [operating features selected by said pilot].

Please add the following new claims.

9
14. (New) The pilot aid as described in claim 1 wherein said digital data base further comprises structure data, said structure data representing manmade structures as one or more polygons.

18
15. (New) The pilot aid as described in claim 7 12 wherein said digital data base further comprises structure data, said structure data representing manmade structures as one or more polygons.

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16. (New) The pilot aid as described in claim 13 23 wherein said digital data base further comprises structure data, said structure data representing manmade structures as one or more polygons.

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17. (New) The pilot aid as described in claim 1 wherein said terrain data is generated from elevation data comprising an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by one or more of said polygons no elevation point within each said polygon is below said plane of each said polygon by a first distance or more.

18. (New) The pilot aid as described in claim 7 wherein said terrain data is generated from elevation data comprising an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by one or more of said polygons no elevation point within each said polygon is below said plane of each said polygon by a first distance or more.

19. (New) The pilot aid as described in claim 13 wherein said terrain is generated from elevation data comprising an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by one or more of said polygons no elevation point within each said polygon is below said plane of each said polygon by a first distance or more.

20. (New) The pilot aid as described in claim 17 wherein in a second region of said terrain represented by one or more of said polygons no elevation point within each said polygon is below said plane of each said polygon in said second region by a second distance or more, said second distance different from said first distance.

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21. (New) The pilot aid as described in claim 18 wherein in a second region of said terrain represented by one or more of said polygons no elevation point within each said polygon is below said plane of each said polygon in said second region by a second distance or more, said second distance different from said first distance.

22. (New) The pilot aid as described in claim 19 wherein in a second region of said terrain represented by one or more of said polygons no elevation point within each said polygon is below said plane of each said polygon in said second region by a second distance or more, said second distance different from said first distance.

23. (New) The pilot aid as described in claim 17 wherein no elevation point within each said polygon in said first region is above said plane of said polygon.

24. (New) The pilot aid as described in claim 18 wherein no elevation point within each said polygon in said first region is above said plane of said polygon.

25. (New) The pilot aid as described in claim 19 wherein no elevation point within each said polygon in said first region is above said plane of said polygon.

26. (New) The pilot aid as described in claim 20 wherein no elevation point within each said polygon in said first region and said second region is above said plane of said polygon.

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27. (New) The pilot aid as described in claim 21 wherein no elevation point within each said polygon in said first region and said second region is above said plane of said polygon.

28. (New) The pilot aid as described in claim 22 wherein no elevation point within each said polygon in said first region and said second region is above said plane of said polygon.

29. (New) A method for producing a terrain data base comprising terrain data, said terrain data represented as one or more polygons, said method comprising the steps of:

providing a plurality of elevation points, each of said plurality of elevation points representing an elevation of a point on a terrain;

defining a polygon having one or more vertices defined by one or more of said elevation points;

examining an adjacent one of said plurality of elevation points to determine if expanding said polygon to an expanded polygon to include said adjacent one of said plurality of elevation points causes one or more of said plurality of elevation points within said expanded polygon to be below a plane of said expanded polygon by a first distance or more; and,

expanding said polygon to include said adjacent one of said plurality of elevation points if none of said elevation points within said expanded polygon is below said plane by said first distance or more.

30. (New) The method as described in claim 29 wherein said adjacent one of said plurality of elevation points is further examined to determine if one or

more of said plurality of elevation points within said expanded polygon is above said plane of said expanded polygon, and said polygon is expanded if none of said elevation points within said expanded polygon is above said plane of said expanded polygon and if none of said elevation points within said expanded polygon is below said plane by said first distance or more.

31. (New) The method as described in claim 23 wherein one or more additional adjacent ones of said plurality of elevation points are examined, and wherein said polygon is expanded to include said one or more additional ones of said plurality of elevation points which do not cause any of said elevation points within said expanded polygon to be below said plane of said expanded polygon by said first distance or more.

32. (New) The method as described in claim 23 wherein one or more additional adjacent ones of said plurality of elevation points are examined, and wherein said polygon is expanded to include said one or more additional ones of said plurality of elevation points which do not cause any of said elevation points within said expanded polygon to be above said plane of said expanded polygon and do not cause any of said elevation points within said expanded polygon to be below said plane of said expanded polygon by said first distance or more.

33. (New) The method as described in claim ~~31~~ 32 wherein said polygon is stored in said terrain data base after all of said elevation points adjacent to said polygon have been examined.

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36
~~34.~~ (New) The method as described in claim 35 ~~32~~ wherein said polygon is stored in said terrain data base after all of said elevation points adjacent to said polygon have been examined.

34
~~35.~~ (New) The method as described in claim 32 ~~31~~ wherein additional polygons are defined, expanded, and added to said terrain database.

36. (New) A method of using an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

locating said aircraft's position in three dimensions;

providing a data base comprising terrain data, said terrain data representing terrain as one or more polygons;

determining said aircraft's orientation in three dimensional space;

accessing said terrain data according to said aircraft's position;

transforming said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and,

displaying said three dimensional projected image data.

37. (New) The method of claim 36 further comprising selecting one or more operating features, wherein said one or more operating features comprise one or more features selected from the group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, and presenting a three dimensional projected image of a route ahead.

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38. (New) The method as described in claim 36 wherein said terrain data base is produced by a method comprising the steps of:

providing a plurality of elevation points, each of said plurality of elevation points representing an elevation of a point on a terrain;

defining a polygon having one or more vertices defined by one or more of said elevation points;

examining an adjacent one of said plurality of elevation points to determine if expanding said polygon to an expanded polygon to include said adjacent one of said plurality of elevation points causes one or more of said plurality of elevation points within said expanded polygon to be below a plane of said expanded polygon by a first distance; and,

expanding said polygon to include said adjacent one of said plurality of elevation points if none of said elevation points within said expanded polygon is below said plane by said first distance or more.

39. (New) The method as described in claim 38 wherein said adjacent one of said plurality of elevation points is further examined to determine if one or more of said plurality of elevation points within said expanded polygon is above said plane of said expanded polygon, and said polygon is expanded if none of said elevation points within said expanded polygon is above said plane of said expanded polygon and if none of said elevation points within said expanded polygon is below said plane by said first distance or more.

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REMARKS

In the Office Action of November 9, 1994, a new title was required. Applicant has supplied herewith a new title which is descriptive of the invention to which the claims are directed. Further, Applicant has made correction to the abstract as requested. In addition, minor informalities throughout the specification have been corrected. In this regard, Applicant notes that the originally filed Figures contain two Figures labeled 12e, and two Figures labeled 13e. Applicant has re-labeled the second Figure in each case to read 12f, and 13f, respectively, on the corrected formal drawings submitted concurrently herewith, and has corrected the specification accordingly.

Claims 1 - 13 were rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention. Applicant has amended the claims, and has provided, below, clarification where requested. Applicant submits that the amendments, and clarification overcome all 35 U.S.C. § 112, second paragraph rejections. However, should the Examiner believe any further § 112 issues remain, any further guidance, including suggested claim language, would be appreciated.

With regard to the phrase "polygon data representing terrain and manmade structure," Applicant has amended the claims to recite that the data base comprises terrain data, wherein the terrain data represents the terrain as one or more polygons. Applicant submits that as described throughout the present specification, the terrain may be represented by a collection of polygons where, for example, an elevation data point may be used as one of the vertices of the polygon. With regard to the phrase "different operating features" Applicant has removed this phrase from the independent claims. Applicant has amended claim 5 to recite that the pilot aid of claim 1 further comprises a control panel to

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selected one or more operating features. Further in this regard, Applicant has more clearly stated, in claim 6, that the functions may include panning, tilting, and zooming a viewpoint of the recited three dimensional projected image. Applicant submits that the terms "pan," "tilt," and "zoom" are well known in the film, video, and computer graphics industries. For example, in the present invention pan may mean to rotate the observer's eyepoint around the yaw axis, tilt may mean to rotate the observer's viewpoint around the pitch axis, and zoom may mean to change the magnification or change the angular field of view. This allows the pilot to "look" at any portion of the terrain. See, for example, page 15, lines 10 - 18 of the present specification.

Further, Applicant has amended the claims to recite that the computer accesses the terrain data according to the aircraft's position. Referring to page 12, lines 19 - 26, and Figures 10a, 10b, 11a, and 11b, the computer uses the plane's position, in one embodiment, by accessing the data in blocks, which blocks are dependent upon the aircraft's position as described. Of course, the present invention is not limited to this embodiment, and other methods of accessing terrain data around the aircraft's position may be used. Further, Applicant has amended the claims to recite that the computer transforms the terrain data according to the aircraft's orientation as described, for example, on page 13, lines 1 - 4. The transformation is described in detail, on pages 16 - 28 of the present application.

Claims 1 - 12 were rejected under 35 U.S.C. § 103 as being unpatentable over *Beckwith et al.* in view of *Behensky et al.* or *Atari Game Corporation's Hard Drivin' Brochure*, or *Atari Game Corporation's Steel Talons Brochure.* The Examiner states that *Beckwith et al.* discloses a digital system for producing a real time video display in perspective of terrain over which an aircraft is passing on the basis of compressed digital data stored on a cassette tape. The data is read by the computer to provide a 3-D perspective on the display. The

Examiner states that *Beckwith et al.* does not disclose that the database contain polygon data representing the terrain. The Examiner states that *Behensky et al.* suggests a driving simulator for a video game which includes the road and other terrain which are produced by mathematically transforming a three dimensional polygon database. The Examiner states that the suggestion of *Behensky et al.* in at least column 2 would have motivated one of ordinary skill in the art to combine with the system of *Beckwith et al.* in order to provide a significant reduction of database storage and a larger geographic area can be stored so it is not necessary to generate a database of each mission.

Applicant respectfully submits that there is no teaching or suggestion to combine the references as suggested by the Examiner and that further, a combination of the references would require significant modifications not taught in the references singly or in combination, to arrive at the present invention. Please note that *Beckwith et al.*, like the present invention, is concerned with displaying a representation of actual terrain. There is nothing therein to suggest using the compressed data described therein to construct polygons, nor is there any teaching or suggestion to combine the method therein with anything contained in a driving simulator.

Referring to *Behensky et al.*, note that the polygons described therein are used to represent a fictional universe. The polygons of *Behensky et al.* do not represent real terrain in any manner, but rather are, instead, essentially "building blocks" which may be accessed from the data base to create the fictional scene through which the driver is driving. Although the Examiner states that the suggestion in column 2 in *Behensky et al.*, wherein the use of a visual scene comprising polygons is disclosed, would have motivated one of ordinary skill in the art to combine with the system of *Beckwith et al.* in order to provide a significant reduction of database storage, there is nothing therein to suggest that these polygons would be useful for representing the terrain of *Beckwith et al.* That is, in *Behensky et al.*, the polygons are disclosed as simply a means to create this fictional, high resolution scene, and there is no suggestion that these visual building blocks be used to represent actual terrain, or how this would be accomplished.

Furthermore, even if the references are combined note that there is no teaching or suggestion of how to modify the combination of *Behensky et al.* and *Beckwith et al.* to arrive at the present invention. Specifically, where, other than the present invention, is there any teaching of constructing polygons based on an array of elevation points? In this regard, note that the data of *Beckwith et al.* from which the perspective view is obtained, comprises grid points several meters apart. As such, this data would be of far too low a resolution to be useful in the system of *Behensky et al.* For example, referring to the *Hard Drivin'* and the *Steel Talons* Brochure, note that such fine details as road markings, signs, etc. are present. These type of details have no use in the system of *Beckwith et al.* In *Beckwith et al.* actual terrain data must be used, and a low resolution perspective view as is provided in *Beckwith et al.* is all that is needed for the purposes of *Beckwith et al.* Note that although *Beckwith et al.* were aware of flight simulation techniques, (column 2, lines 24 - 49) they considered the perspective techniques described therein as being desirable to create a realistic three dimensional view. Thus, *Beckwith et al.* teaches away from the present invention.

Absent the teachings of the present invention, there is nothing in *Beckwith et al.* or *Behensky et al.* that would motivate one of skill in the art to modify the combination of *Beckwith et al.* with *Behensky et al.*, since the compressed data of *Beckwith et al.* appears to be satisfactory for the purposes described therein. For example, note that the Examiner states that *Beckwith et al.* may use these polygons so that it is not necessary to generate a data base of each mission. However, while a game based on a fictional universe may use a library of polygons to create a display of scenes in that universe, the invention of *Beckwith et al.* must create a perspective view based on the data for the actual terrain. Clearly, there is no teaching in either reference as to how actual terrain would be represented by polygons. Additionally, absent the present invention, there exists no motivation to do so. The only such teaching and motivation comes from the present invention.

Claim 13 was rejected under 35 U.S.C. § 103 as being unpatentable over *Beckwith et al.* and *Behensky et al.*, as applied to claims 1 - 12, and further in view of the sales brochure from the *Polhemus* company. Applicant submits, for the above-described reasons, that the claims are unobvious over the combination of *Beckwith et al.* and *Behensky et al.* Furthermore, note the brochure of *Polhemus* makes no mention of its use in the claimed combination, nor does the combination of references teach or suggest that the head mounted display of *Polhemus* would be useful therein. Thus, Applicant submits that claim 13 is further unobvious over the prior art of record.

Applicant has added new claims 14 - 39. Claims 14 - 16 claim that the data base of claims 1, 7, and 13 further comprises structure data. Claims 17 - 19 claim that each of the polygons defines a plane, wherein no elevation point within a first region represented by the polygons is below the plane of each polygon by a first distance or more. In this way, it can be ensured that the terrain represented by a polygon is sufficiently flat for accurate representation as described generally on pages 29 - 30 of the present specification. Applicant submits that this feature is nowhere taught or suggested in the prior art of record. Claims 20 - 22 claim that no elevation point within a second region of terrain represented by one or more polygons is below the plane of the polygons in the second region by a different distance. In this way, some regions such as those surrounding airports, may be represented with greater accuracy, again as described on pages 29 - 30. Claims 23 -28 claim that no elevation point within an expanded polygon is above the plane of the region. Applicant submits that the pilot aid as described in the above-described claims is further unobvious over the prior art of record.

Claims 29 - 35 claim a method of generating the database using elevation points. Applicant submits the claimed method is nowhere taught or suggested anywhere in the prior art of record. Applicant has added claims 36 - 37 which claim a method of presenting a pilot with a synthesized three dimensional projected view of the world. For the reasons discussed in relation to claims 1 - 12, Applicant submits the claimed method is unobvious over the prior art of record. Further, Applicant has added dependent claims 38 - 39 which claim the method of generating the polygons. For the reasons discussed in relation to claims 29 - 35, Applicant submits that these claims are further unobvious over the prior art of record.

For the foregoing reasons, Applicant submits that all objections and rejections have been overcome. Applicant submits that all pending claims are in condition for allowance and allowance of the same is respectfully requested.

Respectfully submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: February 8, 1995

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on February 8, 1995.
Date of Deposit

Carolyn C. Caires
Name of Person Mailing Correspondence

Carolyn C. Caires | 2/8/95
Signature | Date

Attorney's Docket No.: 002055.P002 Patent

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of:	)	
Jed Margolin	)	Examiner: T. Nguyen
Serial No.: 08/274,394	)	Group Art Unit: 2304
Filed: July 11, 1994	)	
For: PILOT AID USING SYNTHETIC REALITY	)	

Commissioner of
Patents and Trademarks
Washington, D.C. 20231

POWER OF ATTORNEY AND
REVOCATION OF PREVIOUS POWERS

Pursuant to 37 C.F.R. § 1.36, the undersigned sole inventor hereby revokes all powers of attorney previously given and appoints

Keith G. Askoff, Reg. No. 33,828; Aloysius T. C. AuYeung, Reg. No. 35,432; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Timothy R. Croll, Reg. No. 36,771; Daniel M. De Vos, Reg. 37,813; Scot A. Griffin, Reg. No. 38,167; Stephen D. Gross, Reg. No. 31,020; David R. Halvorson, Reg. No. 33,395; Michael D. Hartogs, Reg. No. 36,547; Brian Don Hickman, Reg. No. 35,894; George W Hoover II, Reg. No. 32,992; Paul H. Horstmann, Reg. No. 36,167; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg No. 36,172; Stephen L. King, Reg. No. 19,180; Joseph T. Lin, Reg. No. 38,225; Michael J. Mallie, Reg. No. 36,591; James D. McFarland, Reg. No. 32,544; Anthony C. Murabito, Reg. No. 35,295; Kimberley G. Nobles, Reg. No. 38,255; Ronald W. Reagin, Reg. No. 20,340; James H. Salter, Reg. No. 35,668; Robert A. Saltzberg, Reg. No. 36,910; James C. Scheller, Reg. No. 31,195; Edward W. Scott, IV, Reg. No. 36,000; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Allan T. Sponseller, Reg. No. 38,318; John C. Stattler, Reg. No. 36,285; Edwin H. Taylor, Reg. No. 25,129; Lester J. Vincent, Reg. No. 31,460; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my attorneys; and William Donald Davis, Reg. No. 38,428; Thomas X. Li, Reg. No. 37,079; and Edwin A. Sloane, Reg. No. 34,728; my patent agents; of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send all future correspondence to Keith G. Askoff, Reg. No. 33,828, Blakely, Sokoloff, Taylor, & Zafman, 12400 Wilshire Boulevard, Seventh Floor, Los Angeles, California 90025, and direct all telephone calls to the same at (408) 720-8598.

(LJV/cak 11/28/94)

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Carolyn C. Caves
Name of applicant, assignee or Registered Rep.

Carolyn C. Caves 2/8/95
Signature Date

01232

In re the Application of:
Serial No.: 08/274,394
Filing Date: 7/11/94
Inventors: Jed Margolin
Title: **PILOT AID USING SYNTHETIC REALITY**

Attorney Docket No. 002055.P002

THE HONORABLE COMMISSIONER
OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

Sir: Transmitted herewith is an **Amendment** in the above-identified application:

☐ Small entity status of this Application under 37 CFR 1.9 and 1.27 has been established by a verified statement previously submitted.

☐ A verified statement to establish small entity status under 37 CFR 1.9 and 1.27 is enclosed.

______ No additional fee is required.

The fee has been calculated as shown below:

	(Col. 1) Claims remaining after amendment		(Col. 2) Highest no. previously paid for	(Col. 3) Present extra	Small Entity Rate	Small Entity Additional fee	Other than a Small Entity Rate	Other than a Small Entity Additional fee
Total Claims:	39	minus	20	19	x $11.00=	$209.00	x $22.00=	$0.00
Indep. Claims:	5	minus	3	2	x $38.00=	$76.00	x $76.00=	$0.00
☐ First presentation of multiple dependent claim(s)					+ $120.00	$0.00	+ $240.00	$0.00
**If the difference in Col.2 is less than zero, enter "0" in Col. 3					Total Additional:	$285.00	Total Additional:	$0.00

XXX A check in the amount of **$285.00** is attached for presentation of additional claim(s).

☐ Applicant hereby Petitions for an Extension of Time of ________ month(s), pursuant to Rule 1.136(a).

☐ A check in the amount of ________ is attached for processing fees under 37 CFR 1.17.

☐ Please charge my Deposit Account No. **02-2666** the amount of ________. A duplicate copy of this sheet is enclosed.

☐ ____

XXX The Commissioner is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account **02-2666**.

XXX Any additional filing fees required under 37 CFR 1.16 for presentation of extra claims.

XXX Any extension of petition fees under 37 CFR 1.17.

Respectfully submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: February 8, 1995

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Carolyn C. Caires 2/8/95
Date

01233

002055.P002

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	
Jed Margolin	
Serial No.: 08/274,394	Examiner: T. Nguyen
Filed: July 11, 1994	Art Unit: 2304
For: PILOT AID USING SYNTHETIC REALITY	

SUBMISSION OF FORMAL DRAWINGS

Hon. Commissioner of
Patents and Trademarks
Washington, D.C. 20231

Dear Sir:

Enclosed herewith for filing in the above-identified application are 13 sheets of formal drawings.

Respectfully submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: February 8, 1995

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2/8/95
Date

01234

APPROVED | O.G. FIG. 4
BY | CLASS | SUBCLASS
DRAFTSMAN | 364 | 449

08-513,298

5566073

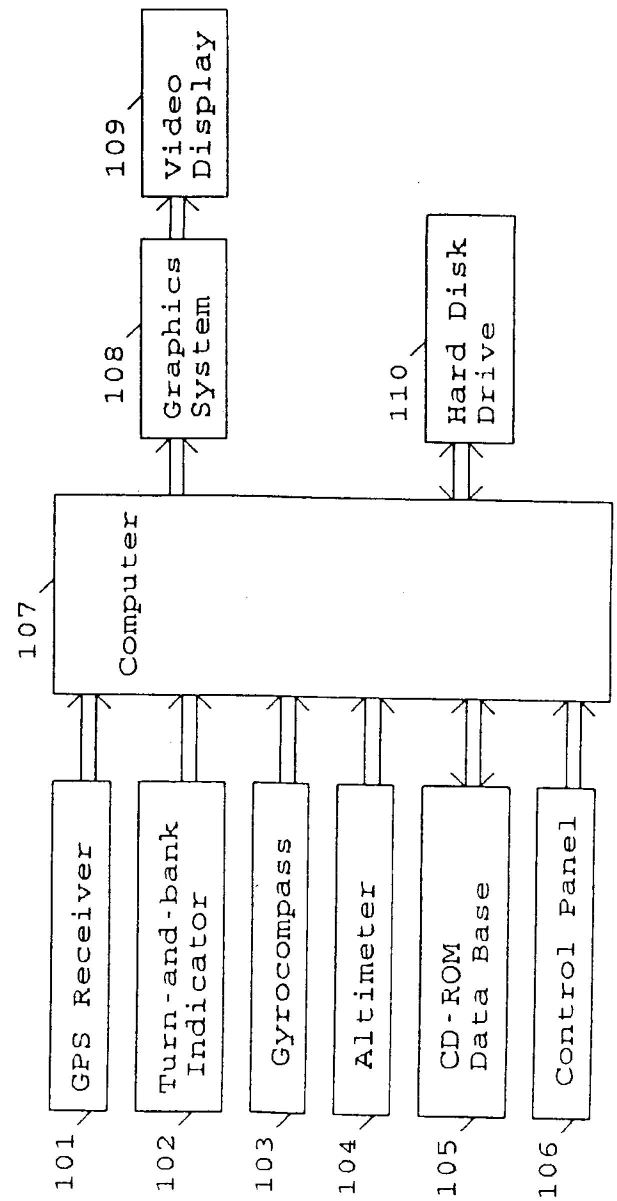

Fig. 1

08 513,298

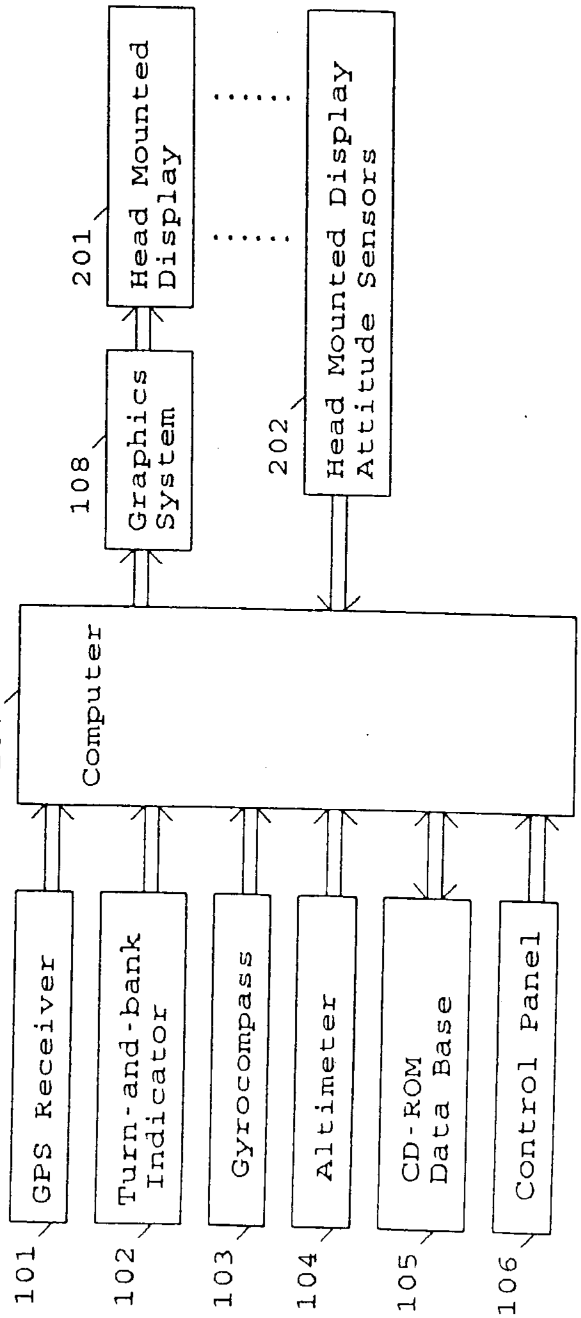

Fig. 2

08-513,298

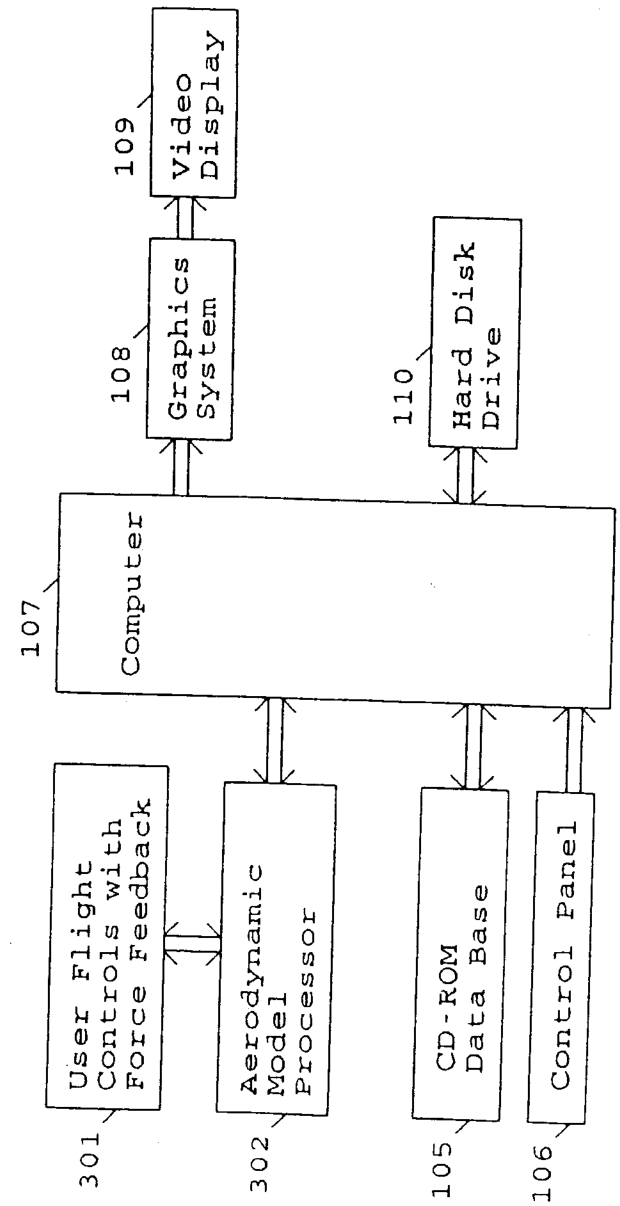

Fig. 3

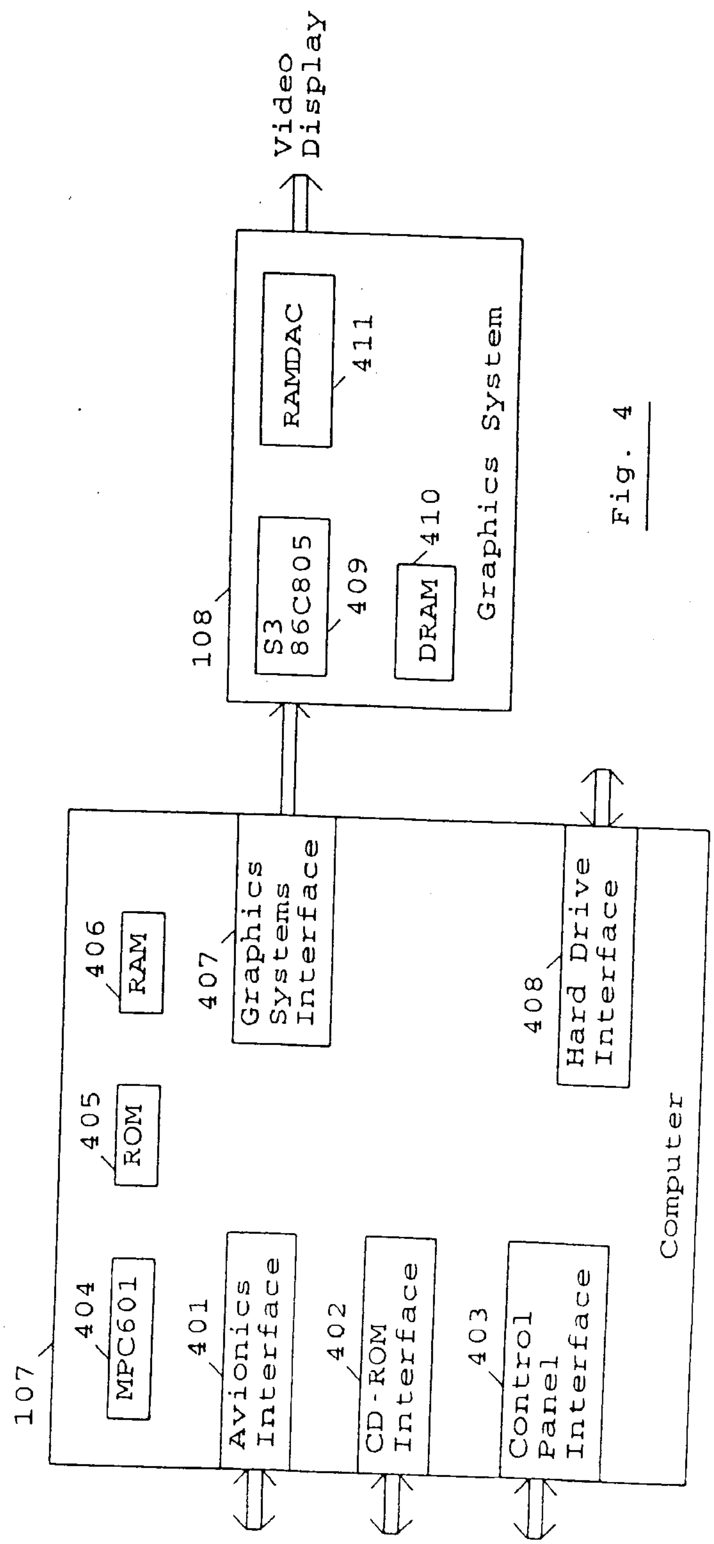
Video Display
RAMDAC
411
108
S3 86C805
409
DRAM
410
Graphics System
107
404
MPC601
405
ROM
406
RAM
407
Graphics Systems Interface
408
Hard Drive Interface
401
Avionics Interface
402
CD-ROM Interface
403
Control Panel Interface
Computer

Fig. 4

08-513,298

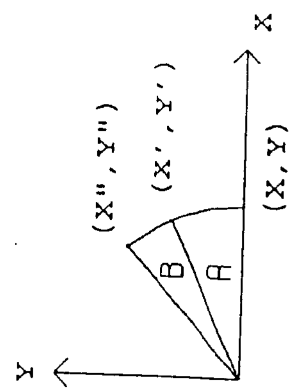

Fig. 5b

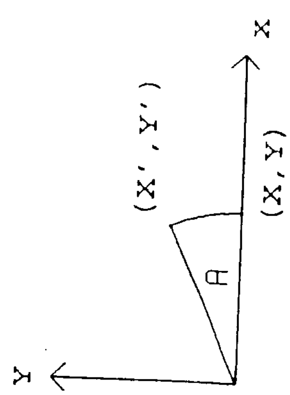

Fig. 5a

08-513,298

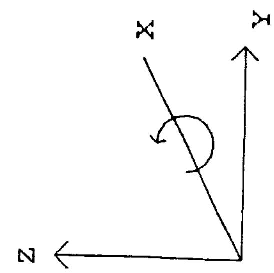

Fig. 6c

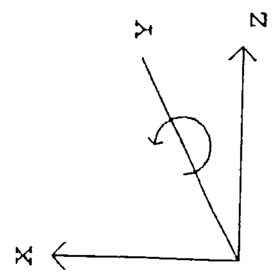

Fig. 6b

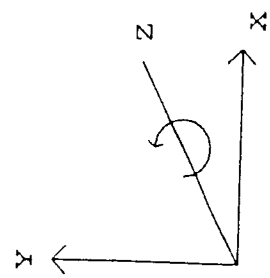

Fig. 6a

08-513,298

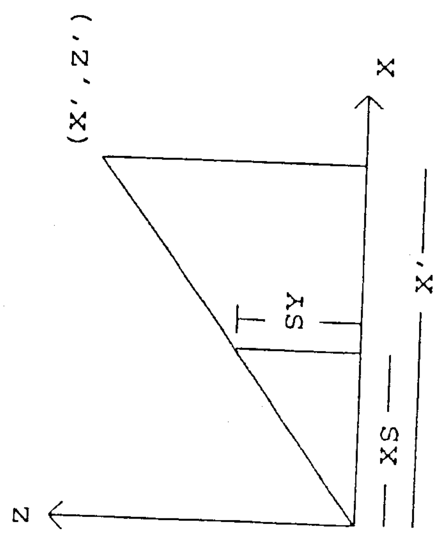

Fig. 7a Side

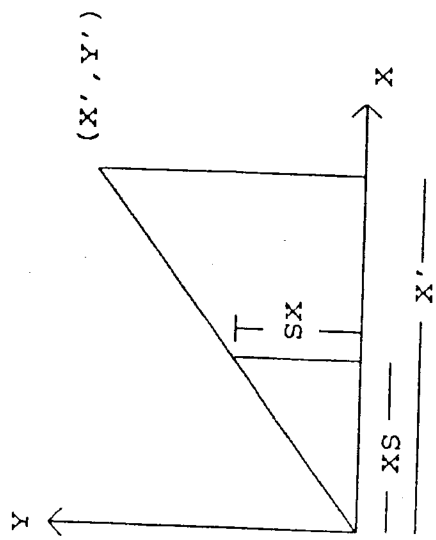

Fig. 7b Top

08-513,298

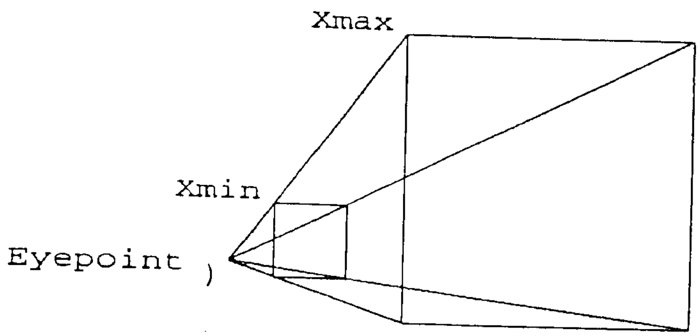

Fig. 8a

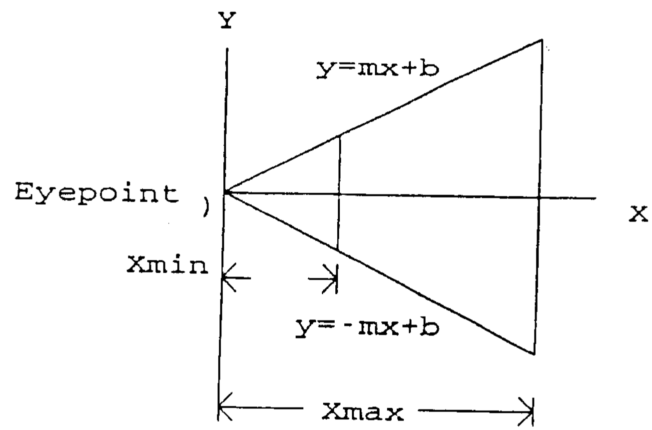

Fig. 8b Top View

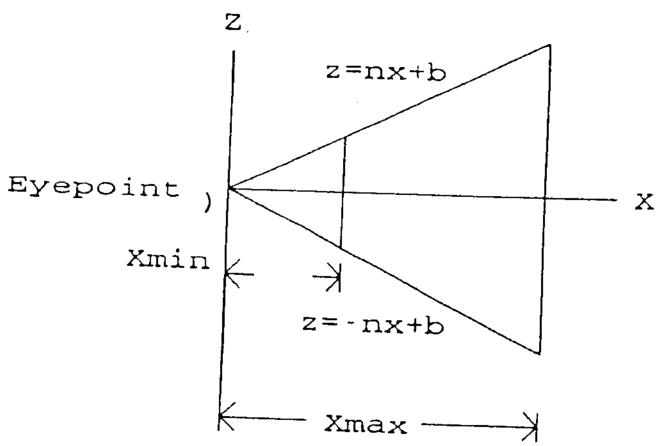

Fig. 8c Side View

08-513,298

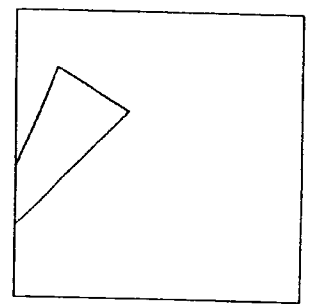

Fig. 9b

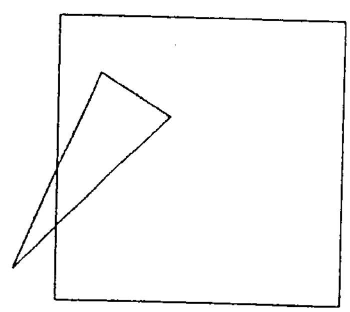

Fig. 9a

08-513,298

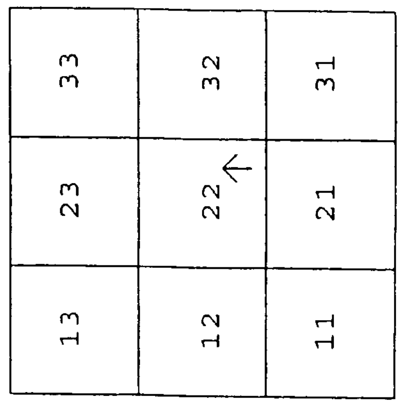

Fig. 10b

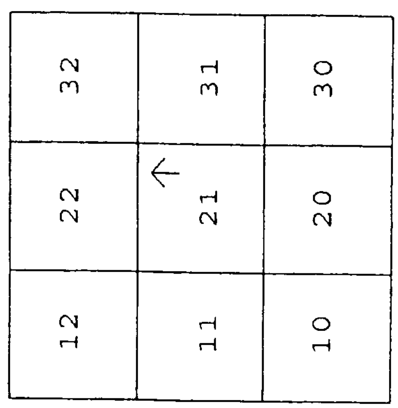

Fig. 10a

08-513,298

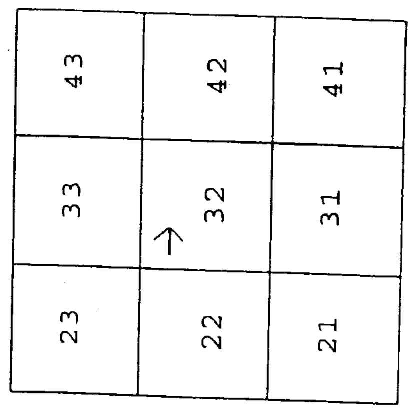

Fig. 11b

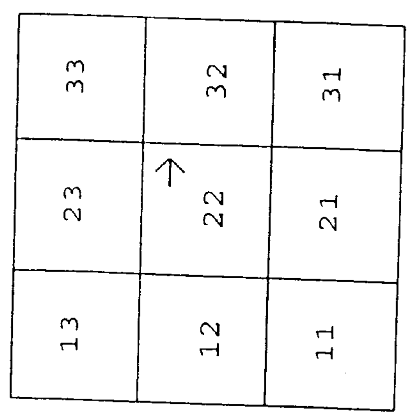

Fig. 11a

08-513,298

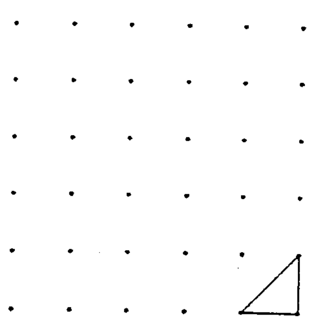

Fig. 12a

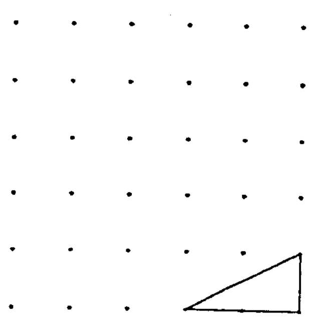

Fig. 12b

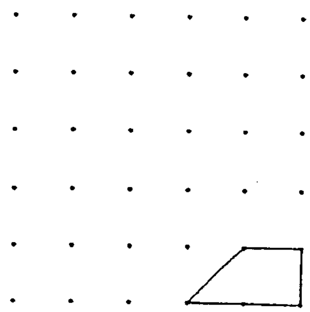

Fig. 12c

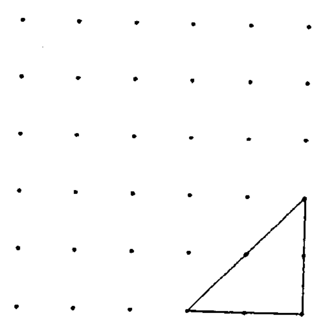

Fig. 12d

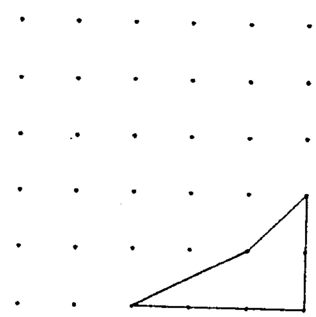

Fig. 12e

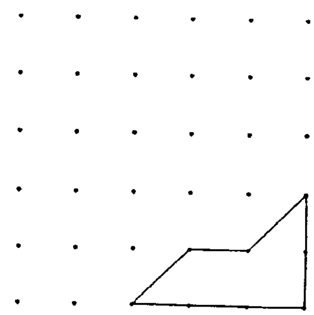

Fig. 12f

08-513,298

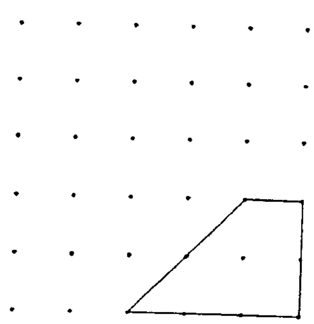

Fig. 13a

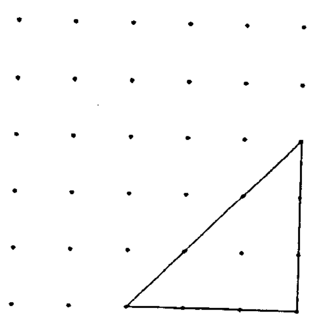

Fig. 13b

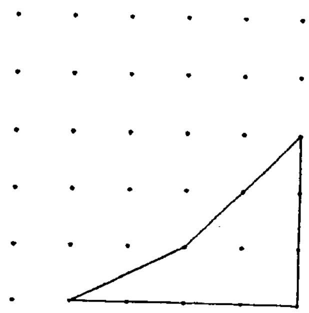

Fig. 13c

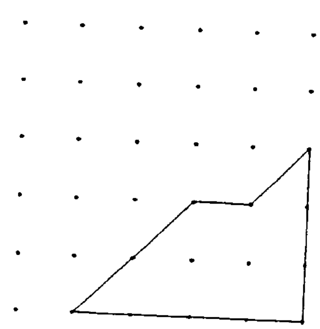

Fig. 13d

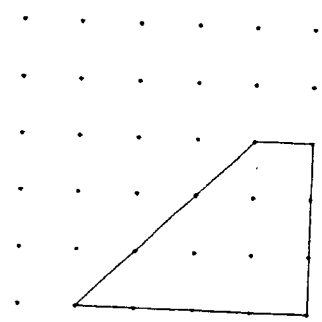

Fig. 13e

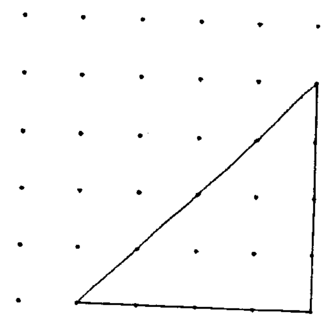

Fig. 13f

76-202-
209-203 GP234

002055.P002

PATENT 5/(A)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
Jed Margolin	)	
Serial No.: 08/274,394	)	Examiner: T. Nguyen
Filed: July 11, 1994	)	Art Unit: 2304
For: PILOT AID USING SYNTHETIC REALITY	)	

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

AMENDMENT AND RESPONSE

Dear Sir:

In response to the Office Action of November 9, 1994, please enter the following amendments and consider the following remarks.

IN THE TITLE

Please delete the entire title and replace it with:

--PILOT AID USING A SYNTHETIC ENVIRONMENT--

IN THE ABSTRACT

Page 36, lines 1-2, please delete "means for determining" and replace it with:

--way to determine--

090 BA 02/27/95 08274394 1 202 76.00 CK

090 BA 02/27/95 08274394 1 203 209.00 CK

01243

IN THE SPECIFICATION

On page 7, line 12, please delete "service" and replace it with: --survey--

On page 7, line 15, please delete "service" and replace it with: --survey--

On page 11, line 9, please delete "12e" and replace it with: --12f--

On page 11, line 9, please delete "13e" and replace it with: --13f--

On page 15, line 10, please delete "104" and replace it with: --106--

On page 16, line 4, please delete "the the" and replace it with: --to the--

On page 29, line 2, please delete "service" and replace it with: --survey--

On page 30, line 16, please delete "12e" and replace it with: --12f--

On page 30, line 17, please delete "13e" and replace it with: --13f--

01249

IN THE CLAIMS

Please amend claims 1 - 13.

1. (Once Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system [means] for locating said aircraft's position in three dimensions;

a digital data base [means containing polygon] comprising terrain data, said terrain data representing terrain as one or more polygons [and manmade structures];

an attitude determining system [means] for determining said aircraft's orientation in three dimensional space;

[a control panel means for allowing said pilot to select different operating features;]

a computer [means for using said aircraft position data] to access said terrain data according to said aircraft's position and [manmade structure data from said digital data base and using said aircraft orientation data] to transform said terrain [and manmade structure] data to provide three dimensional projected image data according to said aircraft's orientation [operating features selected by said pilot];

a display [means] for displaying said three dimensional projected image data.

2. (Once Amended) The pilot aid [position determining means] of claim 1, wherein said position determining system [means] comprises a standard system for receiving and processing data from the global positioning system.

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3. (Once Amended) The pilot aid [attitude determining means] of claim 1, wherein said attitude determining system [means] comprises a standard avionics system.

4. (Once Amended) The pilot aid [digital data base] of claim 1, wherein said digital data base [means] comprises a cd rom disc and cd rom drive.

5. (Once Amended) The pilot aid [control panel means] of claim 1, further comprising a control panel to select one or more operating features [wherein said control panel means selects the functions of pan, tilt, and zoom].

6. (Once Amended) The pilot aid [control panel means] of claim 1, wherein said one or more operating features comprise one or more features selected from the group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, and providing a three dimensional projected image of a route ahead [control panel means permits said pilot to preview the route ahead].

7. (Once Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system [means] for locating said aircraft's position in three dimensions;

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APPENDIX --Standard DLG Distribution Format (Record Contents)

In the standard DLG distribution format, the topological linkages are contained only in the line elements. The files are physically comprised of standard 8-bit ASCII characters organized into fixed-length logical records of 144 characters. Nine distinct record types are defined.

Logical record type	Content
A	Header record containing DLG identification information.
B	Header record containing projection information and registration points.
C	Header record identifying data categories contained in this DLG and indicating the number of nodes, areas, and lines in each category.
D.1	A node or an area record.
D.2	A line record.
E	Record containing x,y coordinate string.
F	Record containing attribute codes.
G	Record containing text string (not currently used).
H	Accuracy estimate (not currently used).

The actual sequence of records in a standard distribution DLG file is as follows:

1. Header records
    - Type A (one record)
    - Type B (one record)
    - Type C (one record)

2. Data records (Repeated for each data category)
    - Node records (Repeated for each node within a data category)
        - Node description (D.1)
        - Attribute codes (F)
        - Text string (G)
    - Area records (Repeated for each area within a data category)
        - Area description (D.1)
        - Attribute codes (F)
        - Text string (G)
    - Line records (Repeated for each line within a data category)
        - Line description (D.2)
        - x,y coordinates (E)
        - Attribute codes (F)
        - Text string (G)

3. Accuracy estimate
    - Type H (one record) (not currently used)

APPENDIX --Sample DLG Data File (Optional Distribution Format)

(Each 80-character record is shown as a single line.)

```
USGS-NMD  DLG DATA - CHARACTER FORMAT - 09-29-82 VERSION
GLEN ELLEN                                                   1968     24000

     3      1     10      2 0.61000000000D+00      4      0      4      1
   -0.122033045000000D+09    0.380180450000000D+08    0.0
    0.0                      0.0                      0.0
    0.0                      0.0                      0.0
    0.0                      0.0                      0.0
    0.0                      0.0                      0.0
  0.10000000000D+01 0.0               0.0                0.0
SW         38.250000 -122.625000         532812.91  4233413.86
NW         38.375000 -122.625000         532757.10  4247282.79
NE         38.375000 -122.500000         543674.93  4247335.01
SE         38.250000 -122.500000         543750.25  4233465.56
BOUNDARIES (24&25)      0     16     16 010      7      7 010     20     20      1
N     1    532812.91   4233413.86           2           0     0
      1    -10
N     2    532757.10   4247282.79           2           0     0
     -2      3
N     3    543674.93   4247335.01           2           0     0
     -6      7
N     4    543750.25   4233465.56           2           0     0
     -9     10
N     5    532773.94   4242301.15           3           0     0
     -1      2     12
N     6    539496.77   4247314.04           3           0     0
     -3      4     17
N     7    541771.16   4247326.01           3           0     0
     -4      5    -19
N     8    542795.89   4247330.85           3           0     0
     -5      6    -14
N     9    543686.72   4244968.57           3           0     0
     -7      8    -15
N    10    543703.06   4242158.35           3           0     0
     -8      9    -20
N    11    540333.59   4246706.56           3           0     0
    -16    -17     18
N    12    541593.59   4245945.02           3           0     0
    -18     19     20
N    13    536379.09   4234192.12           2           0     0
     11    -11
N    14    542800.74   4247208.34           2           1     0
     14     15
     90      1
N    15    537351.64   4243171.97           2           1     0
    -12     13
     90      1
N    16    538780.02   4243415.25           2           1     0
    -13     16
     90      1
```

APPENDIX --Optional DLG Distribution Format (Record Contents)

In the optional DLG distribution format, topological linkages are explicitly encoded for node and area elements as well as for line elements. The files are physically comprised of 8-bit ASCII characters organized into fixed-length logical records of 80 characters (bytes). Bytes 1-72 of each record may contain DLG data, and bytes 73-80 may contain a record sequence number.

The 11 distinct record types used in the optional DLG distribution format may be categorized as header and data records.

Four types of records are considered header records:

- File identification and description records
- Accuracy records (not currently used)
- Control-point identification records
- Data-category identification records

Seven types of records are considered data records:

- Node and area identification records
- Node-to-line linkage records
- Area-to-line linkage records
- Line identification records (also contains line-to-node and line-to-area linkages)
- Coordinate string records
- Attribute code records
- Text records (not currently used)

The actual sequence of records in an optional distribution format DLG file is as follows:

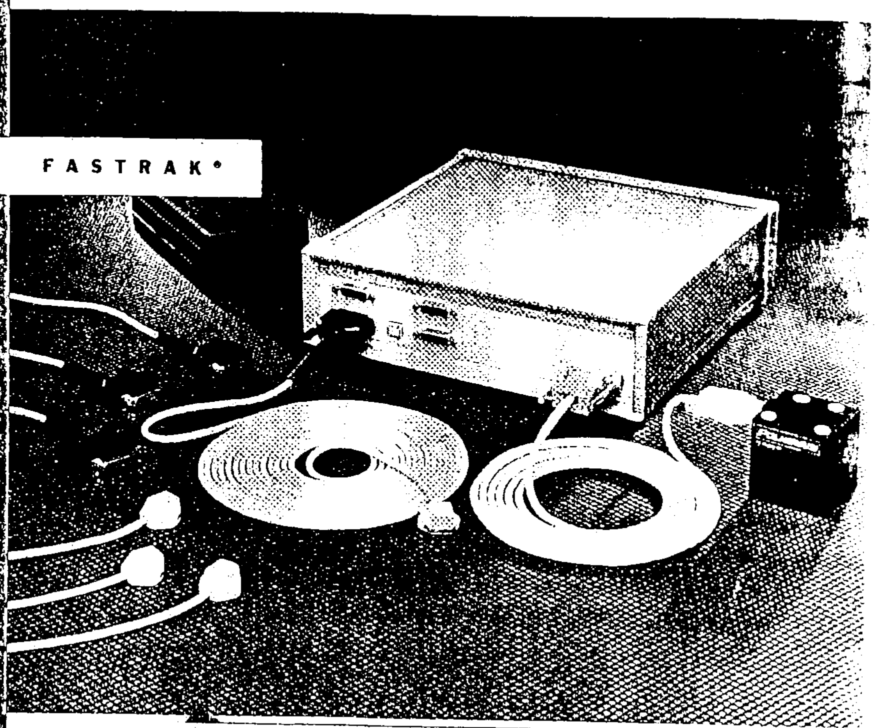
1. Header records
   - Ten file identification and description records
   - Accuracy records (not currently used)
   - Control point identification records (one per control-point)
   - Data category identification records (one per data category in the file)

2. Data records

Records		
Node identification record Node-to-line linkage record(s) Attribute code record(s) Text record(s)	Repeated for each node within a data category	Repeated for each data category
Area identification record Area-to-line linkage record(s) Attribute code record(s) Text record(s)	Repeated for each area within a data category	
Line identification records Coordinate string record(s) Attribute code record(s) Text record(s)	Repeated for each line within a data category	

Polhemus

3SPACE® FASTRAK®



Only FASTRAK [illegible]

COMPONENTS

The 3SPACE FASTRAK includes a System Electronics Unit (SEU), power supply, one receiver, and one transmitter. You can expand the system's capabilities simply by adding up to three additional receivers.

FASTRAK is also available as a board level product for OEM/VAR applications.

▶ **System Electronics Unit** Contains the hardware and software necessary to generate the magnetic fields, compute position and orientation, and interface with the host computer via an RS-232 or IEEE-488 connection. (RS-422 optional)

▶ **Transmitter** The transmitter is a triad of electromagnetic coils, enclosed in a plastic shell, that emits the magnetic fields. The transmitter is the system's reference frame for receiver measurements.

▶ **Receiver** The receiver is a small triad of electromagnetic coils, enclosed in a plastic shell, that detects the magnetic fields emitted by the transmitter. The receiver is a lightweight cube whose position and orientation is precisely measured as it is moved. For 3D mouse applications you can get 3BALL™, which contains the receiver mounted in a convenient ball along with a switch.

FEATURES

▶ **Real Time** Virtually no latency. Digital Signal Processing (DSP) technology provides 4ms latency, updated at 120 Hz. And data are transmitted to the host at up to 100K bytes/sec.

▶ **Improved Accuracy and Resolution** Accuracy of 0.03 in RMS with a resolution of 0.0002 in/in makes this the most precise device of its kind.

01255

The 3SPACE® FASTRAK® accurately computes the position and orientation of a tiny receiver as it moves through space. This device virtually eliminates the problem of latency as it provides dynamic, real time six-degree-of-freedom measurement of position (X, Y, and Z Cartesian coordinates) and orientation (azimuth, elevation, and roll).

FASTRAK is the perfect solution for interfacing with Virtual Reality environments and controlling simulator projectors or other applications where real time response is critical. It is also ideal for measuring range of motion or limb rotation in biomedical research. It is a fast, accurate, easy to use, and effective method of capturing motion data on any non-metallic object.

The FASTRAK system utilizes a single transmitter and can accept data from up to four receivers. If that isn't enough, you can frequency-multiplex up to eight systems (that's 32 receivers) with no change in the update rate. The use of advanced digital signal processing (DSP) technology provides an update rate of 120 Hz (with a single receiver) and a remarkable 4ms latency. The data are then transmitted over a high speed RS-232 interface at up to 115.2K baud or over an even faster IEEE-488 at up to 100K bytes/sec. If your application requires using the system in close proximity to a CRT, FASTRAK has special circuitry to allow you to synchronize with it for improved performance.

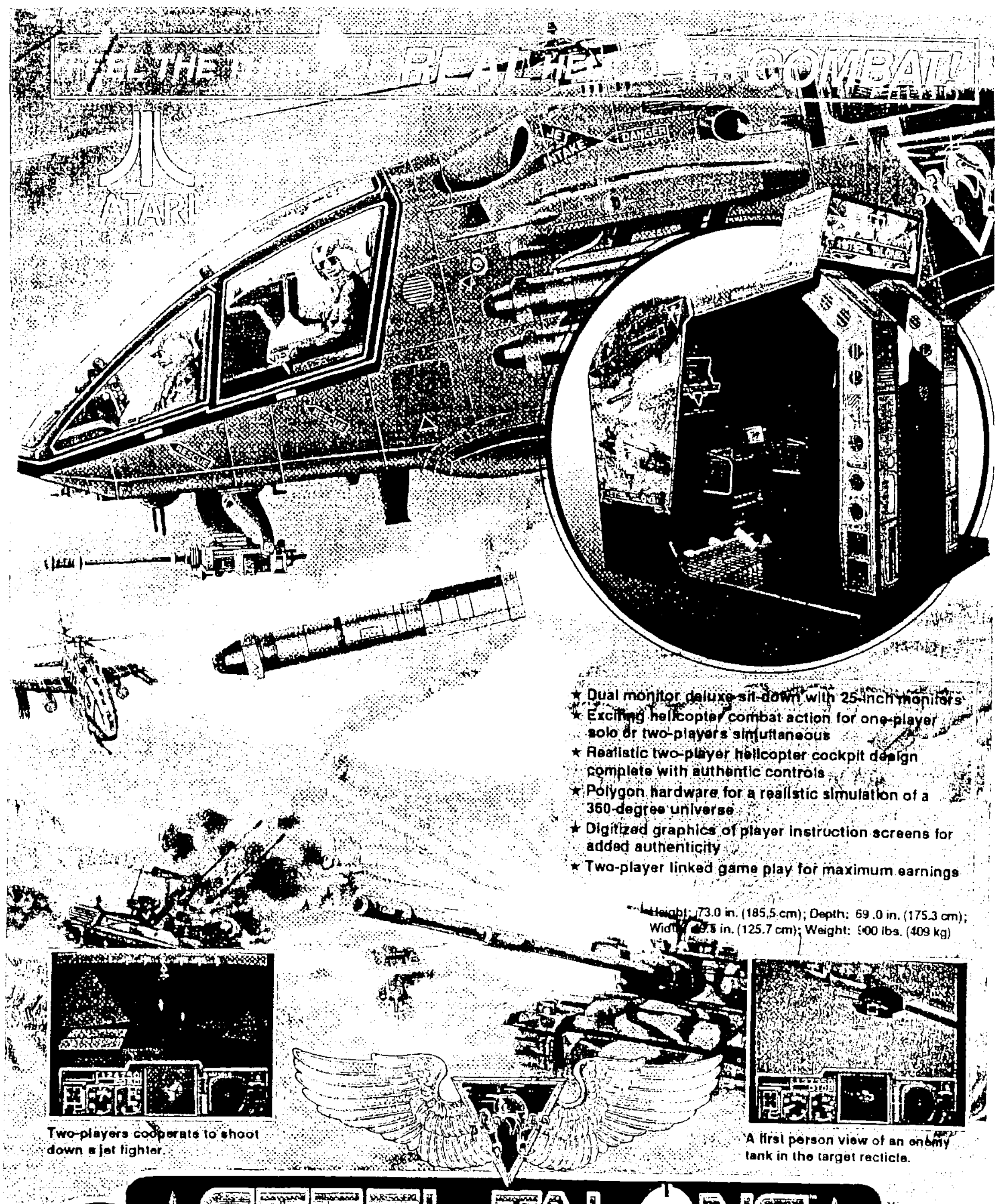
And because FASTRAK uses patented low-frequency magnetic transducing technology, there's no need to worry about maintaining a clear line-of-sight between receiver and transmitter. Polhemus has eliminated the problem of signal blocking that limits sonic or laser devices.

- **Range** Operation over a range up to 10 feet is now possible.
- **Multiple Receiver Operation** Permits measurement of up to 4 receivers on a single system and up to 32 receivers at a time, utilizing eight (8) multiplexed systems.
- **Reliable** From the pioneer in 3D position/orientation measuring devices, in business since 1970. Factory calibrated, never needs adjustment.
- **Multiple Output Formats** Position in cartesian coordinates (in or cm); orientation in direction cosines, Euler angles, or quaternions.

APPLICATIONS

- **Virtual Reality** From the beginning, Polhemus 3SPACE systems have been the systems of choice for VR head and body tracking applications. Now FASTRAK takes you to the next generation with real time tracking.
- **Head Mounted Displays** FASTRAK is the consummate solution for head-mounted displays utilized in military, VR, or simulator applications. FASTRAK virtually eliminates latency (lag).
- **Biomechanical Analysis** Mount up to 32 receivers on parts of the anatomy and collect real time relative movement data for gait and limb analysis. Perfect for leg, joint, spinal, or shoulder rotational measurement.
- **Graphics** The natural way to manipulate graphics for animation or simulation. The receiver, mounted in a mouse, stylus, or other hand held device, is the ideal way to gain real time control over the placement of cameras, light sources, projectors, or any movable image.
- **Stereotaxic Localization** The receiver can be mounted on a non-metallic object (such as a robotic prosthesis) to determine its position and orientation.

01256


ATARI
★ Dual monitor deluxe sit-down with 25-inch monitors
★ Exciting helicopter combat action for one-player solo or two-players simultaneous
★ Realistic two-player helicopter cockpit design complete with authentic controls
★ Polygon hardware for a realistic simulation of a 360-degree universe
★ Digitized graphics of player instruction screens for added authenticity
★ Two-player linked game play for maximum earnings
Height: 73.0 in. (185.5 cm); Depth: 69 .0 in. (175.3 cm);
Width: 49.5 in. (125.7 cm); Weight: 900 lbs. (409 kg)
Two-players cooperate to shoot down a jet fighter.
A first person view of an enemy tank in the target recticle.
STEEL TALONS
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01257

01258

THE WORLD'S FIRST AUTHENTIC DRIVING SIMULATION GAME!
CALIFORNIA
ATARI GAMES
Get Behind the Wheel and Feel the Thrill!
Slide into the contoured seat and adjust it to fit the length of your arms and legs. Place your feet on the gas and clutch, try your hand on the stick shift. Select manual or automatic transmission, turn the ignition key and you're off!
Hard Drivin' might look like an arcade game but it drives like a real car. Don't just take our word for it:
Take Hard Drivin' for a test drive today!
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Atari Games Corporation, 675 Sycamore Drive, P.O. Box 361110, Milpitas, CA 95035-1110 ☎ (408) 434 3700
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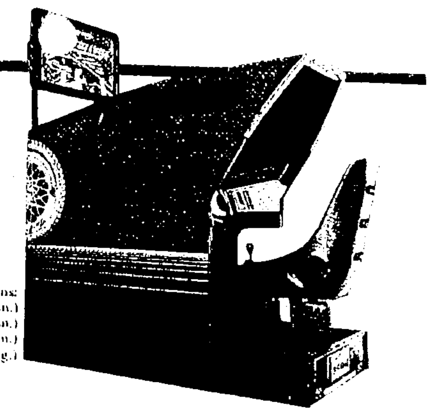
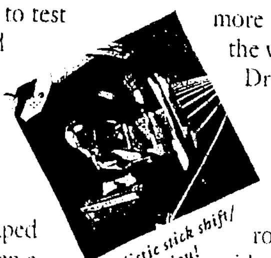
01250

YOUR VEHICLE FOR HIGH-PERFORMANCE EARNINGS!



Deluxe Cockpit Dimensions:
Width: 31 1/2 in. (81 cm.)
Depth(seat in): 62 1/2 in. (160 cm.)
Height: 77 in. (197 cm.)
Weight: 750 lbs. (341 kg.)

How would you like to test drive a high-powered sports car on a stunt course? Now you have your chance, courtesy of Atari Games!



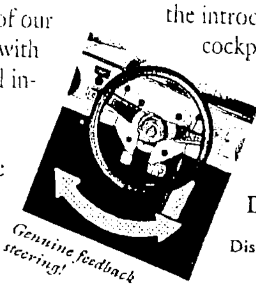
Realistic stick shift/clutch option!

Have you ever jumped a draw bridge or driven a vertical loop? Now you can! These thrilling stunts, among others, provide the ultimate realistic driving experience.

Or, maybe high-speed driving is your type of excitement. Put the pedal to the metal and try to keep control around the corners, weaving in and out of traffic while avoiding oncoming cars. All this and more await you behind the wheel of Hard Drivin'.

Hard Drivin': It's the ride of your life. You feel the tires grip the road as you take a wide turn at high speed. The feedback steering alerts you to the smallest change in the road. You catch air as you fly the draw bridge and land on the down ramp. You are in control as the car holds the road on the vertical loop...

Test the limits of our car and your skill with no risk of personal injury, and follow a course that does not exist anywhere in the real world.



Genuine feedback steering!

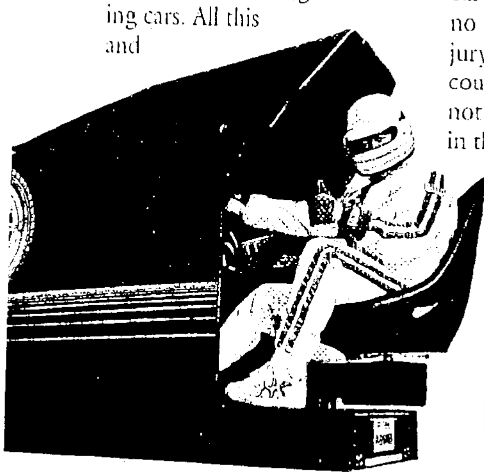
Hard Drivin' is equipped with • center-feel steering with continuous force feedback • adjustable swivel seat • gas, brake and clutch pedals • four-speed stick shift • higher-resolution monitor • instant replay of crash sequences • championship "grudge" match.

Adjustable swivel seat!

After-market options include • dollar bill acceptor • overhead display assembly. • Compact sitdown model will follow the introduction of the deluxe cockpit version depicted herein.

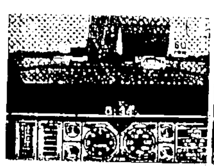
Shift your R.O.I. into high gear with Hard Drivin'!

Distributed By:

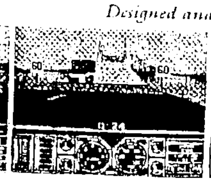


Compact sitdown model will follow.

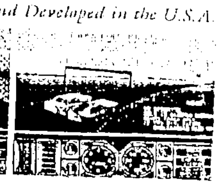
Designed and Developed in the U.S.A.



Exciting stunt track with a 360-degree loop!



A true three-dimensional world presented on the screen!



Qualify and challenge the top Hard Driver!

01200

08/274,394

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
08/274,394	07/11/94	MARGOLIN	

23M1/1109

JED MARGOLIN
3570 PLEASANT ECHO DRIVE
SAN JOSE CA 95148-1916

EXAMINER	
NGUYEN, T	
ART UNIT	PAPER NUMBER
2304	03

DATE MAILED: 11/09/94

This is a communication from the examiner in charge of your application.
COMMISSIONER OF PATENTS AND TRADEMARKS

☒ This application has been examined ☐ Responsive to communication filed on ________ ☐ This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), 0 days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. ☒ Notice of References Cited by Examiner, PTO-892.
2. ☒ Notice of Draftsman's Patent Drawing Review, PTO-948.
3. ☒ Notice of Art Cited by Applicant, PTO-1449. (6 sheets)
4. ☐ Notice of Informal Patent Application, PTO-152.
5. ☐ Information on How to Effect Drawing Changes, PTO-1474.
6. ☐ ________

Part II SUMMARY OF ACTION

1. ☒ Claims 1-13 are pending in the application.

   Of the above, claims ________ are withdrawn from consideration.
2. ☐ Claims ________ have been cancelled.
3. ☐ Claims ________ are allowed.
4. ☒ Claims 1-13 are rejected.
5. ☐ Claims ________ are objected to.
6. ☐ Claims ________ are subject to restriction or election requirement.
7. ☐ This application has been filed with informal drawings under 37 C.F.R. 1.85 which are acceptable for examination purposes.
8. ☐ Formal drawings are required in response to this Office action.
9. ☐ The corrected or substitute drawings have been received on ________. Under 37 C.F.R. 1.84 these drawings are ☐ acceptable; ☐ not acceptable (see explanation or Notice of Draftsman's Patent Drawing Review, PTO-948).
10. ☐ The proposed additional or substitute sheet(s) of drawings, filed on ________, has (have) been ☐ approved by the examiner; ☐ disapproved by the examiner (see explanation).
11. ☐ The proposed drawing correction, filed ________, has been ☐ approved; ☐ disapproved (see explanation).
12. ☐ Acknowledgement is made of the claim for priority under 35 U.S.C. 119. The certified copy has ☐ been received ☐ not been received ☐ been filed in parent application, serial no. ________ ; filed on ________.
13. ☐ Since this application apppears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. ☐ Other

01261

EXAMINER'S ACTION

PTOL-326 (Rev. 2/93)

Part III DETAILED ACTION

1. This application has been examined. Claims 1-13 are pending.

Specification

2. The title of the invention is not descriptive. A new title is required that is clearly indicative of the invention to which the claims are directed.

3. Applicant is reminded of the proper language and format of an Abstract of the Disclosure.

The abstract should be in narrative form and generally limited to a single paragraph on a separate sheet within the range of 50 to 250 words. It is important that the abstract not exceed 250 words in length since the space provided for the abstract on the computer tape used by the printer is limited. The form and legal phraseology often used in patent claims, such as **"means"** and "said", should be avoided (emphasis added). The abstract should describe the disclosure sufficiently to assist readers in deciding whether there is a need for consulting the full patent text for details.

The language should be clear and concise and should not repeat information given in the title. It should avoid using phrases which can be implied, such as, "The disclosure concerns," "The disclosure defined by this invention," "The disclosure describes," *etc.*

Appropriate correction is requested.

Claim Rejections - 35 USC § 112

4. Claim 1-13 are rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

4.1. As per claim 1 (as exemplary of claims 1, 7 and 13), lines 6-7 , the phrase "polygon data representing terrain and manmade structure" is unclear since there is no indication of what the polygon and manmade structure are. Clarification is requested. Furthermore, on lines 10-11, the phrase "difference operating features" is not defined properly. Moreover, the phrase "using said aircraft position data to access said terrain and manmade structure data from said digital data base" on lines 12-13 is unclear since there is no recitation of how to "access" the data from the digital data base by using the aircraft position data. Clarification is requested. In addition, on lines 14-15, the phrase "transform said terrain and manmade structure data to provide three dimensional projected image data" is also unclear since there is no indication of how to transform the terrain and manmade structure data to provide three dimensional projected image data. Clarification is needed.

4.2. As per claim 5 (as exemplary of claims 5 and 11), line 2, the phrase "the functions of pan, tilt, and zoom" is unclear since they are not defined properly.

4.3. As per claim 6 (as exemplary of claims 6 and 12), line 6, the phrase "the route ahead" has no antecedent basis.

4.4. As per claim 7, lines 20-21, the phrase "said aircraft's flight to be displayed at later time" is unclear since the "aircraft flight" is unclear and has no antecedent basis.

4.5. As per claim 13, the instant passage on lines 10-12 is not defined properly. Clarification is requested.

4.6. The remaining claims, not specifically mentioned, are rejected for incorporating the defects from their respective parent by dependency.

5. The following rejections are based on the examiner's best interpretation of the claims in light of the 35 U.S.C. 112 errors noted above.

Claim Rejections - 35 USC § 103

6. The following is a quotation of 35 U.S.C. § 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.
>
> Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the invention was made, owned by the same person or subject to an obligation of assignment to the same person.

Beckwith et al. does not explicitly disclose that a digital data base means containing polygon data representing terrain and manmade structures. However, Behensky et al. suggests a driving simulator for a video game which includes the road and other terrain are produced by mathematically transforming a three-dimensional polygon data base (see at least column 2, lines 33-38). The suggestion of Behensky et al. in at least column 2 would have motivated one of ordinary skill in the art to combine with the system of Beckwith et al. in order to provide a significant reduction of data base storage and a larger geographic areas can be stored so that it is not necessary to generate a data base of each mission. Similarly, the digital data base means containing polygon data representing terrain and manmade structures is also taught in a brochure from Atari Game Corp. (Hard Driving') or a brochure from Atari Game Corp. (Steel Talons). Thus, because of the motivation set forth above, it would have been obvious to a person of ordinary skill in the art at the time the invention was made to combine the teachings of Behensky et al. or the brochure from Atari Game Corp. (Hard Driving') or the brochure from Atari Game Corp. (Steel Talons) with the system of Beckwith et al.

7.2. With respect to claims 2-3 and 8-9, Beckwith et al. discloses the claimed invention as discussed above but does not explicitly discloses that the position determining means comprises a standard system for retrieving and processing data from the global positioning system and the attitude determining means comprises a standard avionics systems. However, the use of the standard system for retrieving and processing data from global positioning system and the standard avionics systems are well known effective and efficient means for determining the position and the orientation of the aircraft. For examples, the Maher patent (4,485,383) shows a receiver for receiving global positioning system and the Timothy patent shows a method for determining the orientation of a moving object form a single GPS receiver and producing roll, pitch, and yaw information. It would have been obvious to one of ordinary skill in the art at the time of the invention to utilize the global positioning system and the standard avionics system in such a system as taught through Beckwith et al. because it would produce high degree of accuracy in determining the position and orientation of the aircraft including roll, pitch, and yaw information.

7.3. With respect to claims 4 and 10, Beckwith et al. does not specifically disclose that the digital data base means comprises a CD rom disc and CD rom drive. However, the use of CD rom disc and CD rom drive for storing data is well known effective and efficient means for storing any data. It would have been obvious to one of ordinary skill in the art at the time of the invention to utilize CD rom disc and CD rom drive in such a system as taught through Beckwith et al. because it would permit high degree of accuracy in the storing and restoring data, random access to the data so that the requirements for cache storage are reduced.

8. Claim 13 is rejected under 35 U.S.C. § 103 as being unpatentable over Beckwith et al and Behensky et al. as applied to claims 1-12 above, and further in view of the sales brochure from the Polhemus company.

Beckwith et al. and Behensky et al. disclose the claimed invention except for a head mounted display means worn by the pilot and an attitude determining means for determining the orientation of the pilot's head in three dimensional space. However, the sales brochure from the Polhemus company suggests the commercial available of a position and orientation sensor which can be used on a head-mounted display. The suggestion of the Polhemus company would have motivated one of ordinary skill in the art to combine the teaching of Polhemus company with the system of Beckwith et al. in order to allow the pilot to have a complete range of motion to receive a synthesized view of the world, a complete unhindered by the aircraft structure. Thus, because of the motivation set forth above, it would have been obvious to a person of ordinary skill in the art at the time the invention was made to combine the teachings in Polhemus's brochure and Beckwith et al. patent.

Conclusion

9. The following references are cited as being of general interest: Lewis (4,028,725), Lerche (4,910,674), Baird et al. (4,954,837), Fitzpatrick et al. (5,072,396), Ferguson et al. (5,192,208), Pitts (5,208,590), and Wells et al. (5,334,991).

10. All claims are rejected.

11. Any inquiry concerning this communication or earlier communications from the examiner should be directed to examiner Tan Nguyen, whose telephone number is (703) 305-9755. The examiner can normally be reached on Monday-Thursday from 7:30 AM-6:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Kevin J. Teska, can be reached on (703) 305-9704. The fax phone number for this Group is (703) 305-9564.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 305-3800.

KEVIN J. TESKA
SUPERVISORY PATENT EXAMINER
GROUP 2300

TN

TAN NGUYEN
November 06, 1994

Form PTO 948 (Rev. 10-93) U.S. DEPARTMENT OF COMMERCE - Patent and Trademark Office Application No. 274394

NOTICE OF DRAFTSPERSON'S PATENT DRAWING REVIEW

PTO Draftpersons review all originally filed drawings regardless of whether they are designated as formal or informal. Additionally, patent Examiners will review the drawings for compliance with the regulations. Direct telephone inquiries concerning this review to the Drawing Review Branch, 703-305-8404.

The drawings filed (insert date) 7/11/94, are:
A.___ not objected to by the Draftsperson under 37 CFR 1.84 or 1.152.
B. ✓ objected to by the Draftsperson under 37 CFR 1.84 or 1.152 as indicated below. The Examiner will require submission of new, corrected drawings when necessary. Corrected drawings must be submitted according to the instructions on the back of this Notice.

1. DRAWINGS. 37 CFR 1.84(a): Acceptable categories of drawings: Black ink. Color.
   - ___ Not black solid lines. Fig(s)___
   - ___ Color drawings are not acceptable until petition is granted.

2. PHOTOGRAPHS. 37 CFR 1.84(b)
   - ___ Photographs are not acceptable until petition is granted.

3. GRAPHIC FORMS. 37 CFR 1.84 (d)
   - ___ Chemical or mathematical formula not labeled as separate figure. Fig(s)___
   - ___ Group of waveforms not presented as a single figure, using common vertical axis with time extending along horizontal axis. Fig(s)___
   - ___ Individuals waveform not identified with a separate letter designation adjacent to the vertical axis. Fig(s)___

4. TYPE OF PAPER. 37 CFR 1.84(e)
   - ___ Paper not flexible, strong, white, smooth, nonshiny, and durable. Sheet(s)___
   - ___ Erasures, alterations, overwritings, interlineations, cracks, creases, and folds not allowed. Sheet(s)___

5. SIZE OF PAPER. 37 CFR 1.84(f): Acceptable paper sizes:
   21.6 cm. by 35.6 cm. (8 1/2 by 14 inches)
   21.6 cm. by 33.1 cm. (8 1/2 by 13 inches)
   21.6 cm. by 27.9 cm. (8 1/2 by 11 inches)
   21.0 cm. by 29.7 cm. (DIN size A4)
   - ___ All drawing sheets not the same size. Sheet(s)___
   - ___ Drawing sheet not an acceptable size. Sheet(s)___

6. MARGINS. 37 CFR 1.84(g): Acceptable margins:

Paper size

	21.6 cm. X 35.6 cm. (8 1/2 X 14 inches)	21.6 cm. X 33.1 cm. (8 1/2 X 13 inches)	21 cm. X 27.9 cm. (8 1/2 X 11 inches)	21 cm. X 29.7 cm. (DIN Size A4)
T	5.1 cm. (2")	2.5 cm. (1")	2.5 cm. (1")	2.5cm.
L	.64 cm. (1/4")	.64 cm. (1/4")	.64 cm. (1/4")	2.5 cm.
R	.64 cm. (1/4")	.64 cm. (1/4")	.64 cm. (1/4")	1.5 cm.
B	.64 cm. (1/4")	.64 cm. (1/4")	.64 cm. (1/4")	1.0 cm.

Margins do not conform to chart above.
Sheet(s)___
___ Top (T) ___ Left (L) ___ Right (R) ___ Bottom (B)

7. VIEWS. 37 CFR 1.84(h)
   REMINDER: Specification may require revision to correspond to drawing changes.
   - ___ All views not grouped together. Fig(s)___
   - ___ Views connected by projection lines. Fig(s)___
   - ___ Views contain center lines. Fig(s)___

Partial views. 37 CFR 1.84(h)(2)
   - ___ Separate sheets not linked edge to edge. Fig(s)___
   - ___ View and enlarged view not labeled separately. Fig(s)___
   - ___ Long view relationship between different parts not clear and unambiguous. 37 CFR 1.84(h)(2)(ii) Fig(s)___

Sectional views. 37 CFR 1.84(h)(3)
   - ___ Hatching not indicated for sectional portion of an object. Fig(s)___
   - ___ Hatching of regularly spaced oblique parallel lines not spaced sufficiently. Fig(s)___
   - ___ Hatching not at substantial angle to surrounding axes or principal lines. Fig(s)___
   - ___ Cross section not drawn same as view with parts in cross section with regularly spaced parallel oblique strokes. Fig(s)___
   - ___ Hatching of juxtaposed different elements not angled in a different way. Fig(s)___

Alternate position. 37 CFR 1.84(h)(4)
   - ___ A separate view required for a moved position. Fig(s)___

Modified forms. 37 CFR 1.84(h)(5)
   - ___ Modified forms of construction must be shown in separate views. Fig(s)___

8. ARRANGEMENT OF VIEWS. 37 CFR 1.84(i)
   - ___ View placed upon another view or within outline of another. Fig(s)___
   - ___ Words do not appear in a horizontal, left-to-right fashion when page is either upright or turned so that the top becomes the right side, except for graphs. Fig(s)___

9. SCALE. 37 CFR 1.84(k)
   - ___ Scale not large enough to show mechanism without crowding when drawing is reduced in size to two-thirds in reproduction. Fig(s)___
   - ___ Indication such as "actual size" or "scale 1/2" not permitted. Fig(s)___
   - ___ Elements of same view not in proportion to each other. Fig(s)___

10. CHARACTER OF LINES, NUMBERS, & LETTERS. 37 CFR 1.84(l)
   - ___ Lines, numbers & letters not uniformly thick and well defined, clean, durable, and black (except for color drawings). Fig(s)___

11. SHADING. 37 CFR 1.84(m)
   - ___ Shading used for other than shape of spherical, cylindrical, and conical elements of an object, or for flat parts. Fig(s)___
   - ___ Solid black shading areas not permitted. Fig(s)___

12. NUMBERS, LETTERS, & REFERENCE CHARACTERS. 37 CFR 1.84(p)
   - ___ Numbers and reference characters not plain and legible. 37 CFR 1.84(p)(1) Fig(s)___
   - ___ Numbers and reference characters used in conjunction with brackets, inverted commas, or enclosed within outlines. 37 CFR 1.84(p)(1) Fig(s)___
   - ___ Numbers and reference characters not oriented in same direction as the view. 37 CFR 1.84(p)(1) Fig(s)___
   - ___ English alphabet not used. 37 CFR 1.84(p)(2) Fig(s)___
   - X Numbers, letters, and reference characters do not measure at least .32 cm. (1/8 inch) in height. 37 CFR 1.84(p)(3) Fig(s) 1-8 in Parts

13. LEAD LINES. 37 CFR 1.84(q)
   - ___ Lead lines cross each other. Fig(s)___
   - ___ Lead lines missing. Fig(s)___
   - ___ Lead lines not as short as possible. Fig(s)___

14. NUMBERING OF SHEETS OF DRAWINGS. 37 CFR 1.84(t)
   - ___ Number appears in top margin. Fig(s)___
   - ___ Number not larger than reference characters. Fig(s)___
   - ___ Sheets not numbered consecutively, and in Arabic numerals, beginning with number 1. Sheet(s)___

15. NUMBER OF VIEWS. 37 CFR 1.84(u)
   - ___ Views not numbered consecutively, and in Arabic numerals, beginning with number 1. Fig(s)___
   - ___ View numbers not preceded by the abbreviation Fig. Fig(s)___
   - ___ Single view contains a view number and the abbreviation Fig. Numbers not larger than reference characters Fig(s)___

16. CORRECTIONS. 37 CFR 1.84(w)
   - ___ Corrections not durable and permanent. Fig(s)___

17. DESIGN DRAWING. 37 CFR 1.152
   - ___ Surface shading shown not appropriate. Fig(s)___
   - ___ Solid black shading not used for color contrast. Fig(s)___

ATTACHMENT TO PAPER NO. 3 REVIEWER [signature] DATE 7/27/94

01269

TO SEPARATE, HOLD TOP AND BOTTOM EDGES, SNAP—APART AND DISCARD CARBON

08-513,298

FORM PTO-892 (REV. 2-92) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

NOTICE OF REFERENCES CITED

SERIAL NO.	GROUP ART UNIT	ATTACHMENT TO PAPER NUMBER
~~08/274,294~~	2304	3

APPLICANT(S): MARGOLIN

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
	A	4028725	06/77	LEWIS	340	980	
*	B	4660157	04/87	BECKWITH ET AL	395	101	
	C	4910674	03/90	LERCHE	364	443	
	D	4954837	09/90	BAIRD	364	449	
*	E	5005148	04/91	BEHENSKY ET AL.	364	578	
	F	5072396	12/91	FITZPATRICK ET AL.	364	450	
	G	5192208	03/93	FERGUSON ET AL.	342	169	
	H	5208590	05/93	PITTS	340	973	
	I	5334991	08/94	WELLS ET AL.	340	705	05/92
	J						
	K						

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

*		
*	R	Polhemus, P.O. Box 560, Colchester, VT, Sales brochure for 3D head tracker, Jan. 1994
*	S	Atari Games Corp. 675 Sycamore Dr., Milpitas, CA 95035, Sales brochure for coin-operated video game with 3D, 1991
*	T	Atari Game Corp, 675 Sycamore, Milpitas, CA 95035, Sales brochure for coin-operated video game with 3D polygon-based graphic ("Hard Drivin'") 1988
	U	

EXAMINER	DATE
Tan Nguyen	11/06/94

* A copy of this reference is not being furnished with this office action. (See Manual of Patent Examining Procedure, section 707.05 (a).)

01270

PATENT APPLICATION SERIAL NO. 274394

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

100 MG 07/22/94 08274394 1 201 355.00 CK

PTO-1556
(5/87)

PATENT APPLICATION SERIAL NO. 08/513298

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

01272

PTO-1556
(5/87)

08-513,298

ABSTRACT

A pilot aid using synthetic reality consists of a ~~means for determining~~ ways to determine the aircraft's position and attitude such as by the global positioning system (GPS), a digital data base containing three-dimensional polygon data for terrain and manmade structures, a computer, and a display. The computer uses the aircraft's position and attitude to look up the terrain and manmade structure data in the data base and by using standard computer graphics methods creates a projected three-dimensional scene on a cockpit display. This presents the pilot with a synthesized view of the world regardless of the actual visibility. A second embodiment uses a head-mounted display with a head position sensor to provide the pilot with a synthesized view of the world that responds to where he or she is looking and which is not blocked by the cockpit or other aircraft structures. A third embodiment allows the pilot to preview the route ahead or to replay previous flights.

355.00

301
08-513,298 A
[redacted]

Patent Application of

Jed Margolin

for

PILOT AID USING A SYNTHETIC ~~REALITY~~ ENVIRONMENT

add C1

BACKGROUND OF THE INVENTION

This invention relates to a pilot aid for synthesizing a view of the world. When flying under Visual Flight Rules (VFR) the normal procedure for determining your position is to relate what you see out the window to the information on a paper map. During the day it can be difficult to determine your location because the desired landmark can be lost in the clutter of everything else. When flying at night you see mostly lights. When flying under Instrument Flight Rules (IFR) you must relate the information from various navigation aids to the information on a printed map. You must then interpret the map information in order to avoid flying into objects such as mountains and the like. An improvement in this situation came about when the global positioning system (GPS) became operational and available for civilian use. GPS directly provides map coordinates but you must still, however, interpret the map information. Systems have been developed which use GPS coordinates to access an electronic map which is presented on a display as a flat map. Systems have also been developed that present an apparent three-dimensional effect and some that present a mathematically correct texture-mapped three-dimensional projected display.

Both of these systems require a very large amount of storage for terrain data. The latter system also requires specialized hardware. Their high cost have prevented their widespread adoption by the avaiation community.

The 1984 patent to Taylor et al. (U.S. Patent No. 4,445,118) shows the basic operation of the global positioning system (GPS).

The 1984 patent to Johnson et al. (U.S. Patent No. 4,468,793) shows a receiver for receiving GPS signals.

The 1984 patent to Maher (U.S. Patent No. 4,485,383) shows another receiver for receiving GPS signals.

The 1986 patent to Evans (U.S. Patent No. 4,599,620) shows a method for determining the orientation of a moving object and producing roll, pitch, and yaw information.

The 1992 patent to Timothy et al. (U.S. Patent No. 5,101,356) also shows a method for determining the orientation of a moving object and producing roll, pitch, and yaw information.

The 1993 patent to Ward et al. (U.S. Patent No. 5,185,610) shows a method for determining the orientation of a moving object from a single GPS receiver and producing roll, pitch, and yaw information.

The 1992 patent to Fraughton et al. (U.S. Patent No. 5,153,836) shows a navigation, surveillance, emergency location, and collision avoidance system and method whereby each craft determines its own position using LORAN or GPS and transmits it on a radio channel along with the craft's identification information. Each craft also receives the radio channel and thereby can determine the position and identification of other craft in the vicinity.

The 1992 patent to Beckwith et al. (U.S. Patent No. 5,140,532) provides a topographical two-dimensional real-time display of the terrain over which the aircraft is passing, and a slope-shading technique incorporated into the system provides to the display an apparent three-dimensional effect similar to that provided by a relief map. This is accomplished by reading compressed terrain data from a cassette tape in a controlled manner based on the instantaneous geographical location of the aircraft as provided by the aircraft navigational computer system, reconstructing the compressed data by suitable processing and writing the reconstructed data into a scene memory with a north-up orientation. A read control circuit then controls the read-out of data from the scene memory with a heading-up orientation to provide a real-time display of the terrain over which the aircraft is passing. A symbol at the center of display position depicts the location of the aircraft with respect to the terrain, permitting the pilot to navigate the aircraft even under conditions of poor visibility. However, the display provided by this system is in the form of a moving map rather than a true perspective display of the terrain as it would appear to the pilot through the window of the aircraft.

The 1987 patent to Beckwith et al. (U.S. Patent No. 4,660,157) is similar to U.S. Patent No. 5,140,532. It also reads compressed terrain data from a cassette tape in a controlled manner based on the instantaneous geographical location of the aircraft as provided by the aircraft navigational computer system and reconstructs the compressed data by suitable processing and writing the reconstructed data into a scene memory. However, instead of providing a topographical two-dimensional display of the terrain over which the aircraft is passing and using a slope-shading technique to provide an apparent three-dimensional effect similar to that provided by a relief map as shown in the '532 patent, the '157 patent processes the data to provide a 3D perspective on the display. There are a number of differences between the '157 patent and the present invention:

1. The '157 Patent stores the map as a collection of terrain points with associated altitudes; the large amount of storage required by this approach requires that a tape be prepared for each mission.
   The present invention stores terrain data as a collection of polygons which results in a significant reduction of data base storage; larger geographic areas can be stored so that it it not necessary to generate

a data base for each mission.

2. The '157 Patent uses a tape cassette for data base storage; the long access time for tape storage makes it necessary to use a relatively large cache memory. The present invention uses a CD-ROM which permits random access to the data so that the requirements for cache storage are reduced.
3. The '157 Patent accounts for the aircraft's heading by controlling the way the data is read out from the tape. Different heading angles result in the data being read from a different sequence of addresses. Since addresses exist only at discrete locations, the truncation of address locations causes an unavoidable change in the map shapes as the aircraft changes heading. The present invention stores terrain as polygons which are mathematically rotated as the aircraft changes attitude. The resolution is determined by number of bits used to represent the vertices of the polygons, not the number of storage addresses.
4. The '157 accounts for the roll attitude of the aircraft by mathematically rotating the screen data after it is projected. The '157 Patent does not show the display being responsive to the pitch angle of the aircraft. In systems such as this the lack of fidelity is apparent to the user. People know what things are supposed to look like and how they are supposed to change perspective when they move. The present invention uses techniques that have long been used by the computer graphics industry to perform the mathematically correct transformation and projection.
5. The '157 shows only a single cockpit display while one of the embodiments of the present invention shows a stereographic head-mounted display with a head sensor. The pilot is presented with a synthesized view of the world that is responsive to wherever the pilot looks; the view is not blocked by the cockpit or other aircraft structures. This embodiment is not anticipated by the '157 patent.

The 1991 patent to Behensky et al. (U.S. Patent No. 5,005,148) shows a driving simulator for a video game. The road and other terrain are produced by mathematically transforming a three-dimensional polygon data base.

The first sales brochure from Atari Games Corp. is for a coin-operated game (Hard Drivin') produced in 1989 and relates to the '148 patent. The terrain is represented by polygons in a three-dimensional space. Each polygon is transformed mathematically according to the position and orientation of the player. After being tested to determine whether it is visible and having the appropriate illumination function performed, it is clipped and projected onto the display screen. These operations are in general use by the computer graphics industry and are well known to those possessing ordinary skill in the art.

The second sales brochure from Atari Games Corp. is for a coin-operated game (Steel Talons) produced in 1991 and which also relates to the '148 patent and the use of polygons to represent terrain and other objects.

The 1993 patent to Dawson et al. (U.S. Patent No. 5,179,638) shows a a method and apparatus for providing a texture mapped perspective view for digital map systems which includes a geometry engine that receives the elevation posts scanned from the cache memory by the shape address generator. A tiling engine is then used to transform the elevation posts into three-dimensional polygons. There are a number of differences between the '638 patent and the present invention:

1. The '638 Patent is for a digital map system only. The matter of how the location and attitude are selected is not addressed. The present invention uses a digital map as part of a system for presenting an aircraft pilot with a synthesized view of the world regardless of the actual visibility.
2. The '638 Patent stores the map as a collection of terrain points with associated altitudes, thereby requiring a large amount of data storage.

The terrain points are transformed into polygons during program run-time, thereby adding to the processing burden. The present invention stores terrain data as a collection of polygons which results in a significant reduction of data base storage.

3. The present invention also teaches the use of a stereographic head-mounted display with a head sensor. The pilot is presented with a synthesized view of the world that is responsive to wherever the pilot looks; the view is not blocked by the cockpit or other aircraft structures. This embodiment is not anticipated by the '638 patent.

The 1994 patent to Hamilton et al. (U.S. Patent No. 5,296,854) shows a helicopter virtual display system in which the structual outlines corresponding to structual members forming the canopy structure are added to the head-up display in order to replace the canopy structure clues used by pilots which would otherwise be lost by the use of the head-up display.

The 1994 patent to Lewins (U.S. Patent No. 5,302,964) shows a head-up display for an aircraft and incorporates a cathode-ray tube image generator with a digital look-up table for distortion correction. An optical system projects an image formed on the CRT screen onto a holographic mirror combiner which is transparent to the pilot's direct view through the aircraft windshield.

The sales brochure from the Polhemus company shows the commercial availability of a position and orientation sensor which can be used on a head-mounted display.

The article from EDN magazine, January 7, 1993, pages 31-42, entitled "System revolutionizes surveying and navigation" is an overview of how the global positioning system (GPS) works and lists several manufacturers of commercially available receivers. The article also mentions several applications such as the use by geologists to monitor fault lines, by oil companies for off-shore oil explorations, for keeping track of lower-orbit satellites, by fleet vehicle operators to keep track of their fleet, for crop sprayers to spread fertilizer and pesticides more efficiently, and for in-car systems to display maps for automotive navigation.

The section from "Aviator's Guide to GPS" presents a history of the GPS program.

The sales brochure from Megellan Systems Corp. is for commercially available equipment comprising a GPS receiver with a moving map display. The map that is displayed is a flat map.

The sales brochure from Trimble Navigation is for a commercially available GPS receiver.

The sales brochure from the U.S. Geological ~~Service~~ Survey shows the availability of Digital Elevation Models for all of the United States and its territories.

The second sales brochure from the U.S. Geological ~~Service~~ Survey shows the availability of Digital Line Graph Models for all of the United States and its territories. The data includes: political and administrative boundaries; hydrography consisting of all flowing water, standing water, and wetlands; major transportation systems consisting of roads and trails, railroads, pipelines, transmission lines, and airports; and significant manmade structures.

The Washington Sectional Aeronautical Chart is a paper map published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration that shows the complexity of the information that an aircraft pilot needs in order to fly in the area covered by the map. The other areas of the U.S. are covered by similar maps.

The sales brochure from Jeppesen Sanderson shows that the company makes its navigation data base available in computer readable form.

Accordingly, several objects and advantages of my invention are to provide a system that produces a mathematically correct three-dimensional projected view of the terrain while reducing the amount of storage required for the data base and which can be accomplished by using standard commercially available components. The invention can be used as a real-time inflight aid or it can be used to preview a flight, or it can be used to replay and review a previous flight.

Further objects and advantages of my invention will become apparant from a consideration of the drawings and ensuing description.

SUMMARY OF THE INVENTION

The present invention is a pilot aid which uses the aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three-dimensional projected view of the world. The three-dimensional position is typically determined by using the output of a commercially available GPS receiver. As a safety check, the altitude calculated by the GPS receiver can be compared to the output of either a standard altimeter or a radio altimeter. Attitude can also be determined from the use of a GPS receiver or it can be derived from standard avionic instruments such as turn-and-bank indicator and gyrocompass. The digital data base represents the terrain and manmade structures as collections of polygons in order to minimize storage requirements. The pilot can select several feature such as pan, tilt, and zoom which would allow the pilot to see a synthesized view of terrain that would otherwise be blocked by the aircraft's structure, especially on a low-wing aircraft. The pilot can also preview the route either inflight or on the ground. Because the system has the ability to save the flying parameters from a flight, the pilot can replay all or part of a previous flight, and can even take over during the replay to try out different flight strategies. Through the use of a head-mounted display with a head sensor, the pilot can have complete range of motion to receive a synthesized view of the world, completely unhindered by the aircraft structure.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the output to a single video display.

FIG. 2 is a block diagram showing the output to a head-mounted display.

FIG. 3 is a block diagram showing a system used to plan and/or replay a particular flight.

FIG. 4 is a block diagram showing Computer 107 and Graphics System 108 in FIG. 1, FIG. 2, and FIG. 3.

FIG. 5a shows a simple positive (counter-clockwise) rotation of a point around the origin of a 2-Dimensional space.

FIG. 5b shows a second positive (counter-clockwise) rotation of a point around the origin of a 2-Dimensional space.

FIG. 6a shows the equivalent three dimensional space of FIG. 5a where the rotation is around the Z axis.

FIG. 6b is a re-orientation of the axes of FIG. 6a showing rotation around the Y axis.

FIG. 6c is a re-orientation of the axes of FIG. 6a showing rotation around the X axis.

FIG. 7a is a side view showing the projection of a point in three-dimensions projected onto a two-dimensional screen.

FIG. 7b is a top view showing the projection of a point in three-dimensions projected onto a two-dimensional screen.

FIG. 8a is a cabinet-projected three-dimensional representation of the viewing pyramid.

FIG. 8b is a 2D top view of the viewing pyramid.

FIG. 8c is a 2D side view of the viewing pyramid.

FIG. 9a shows an unclipped polygon.

FIG. 9b shows how clipping the polygon in FIG. 9a produces additional sides to the polygon.

FIG. 10a shows the impending crossover from Geographic Data Block 21 to Geographic Data Block 22.

FIG. 10b shows the result of a crossover from Geographic Data Block 21 to Geographic Data Block 22.

FIG. 11a shows the impending crossover from Geographic Data Block 22 to Geographic Data Block 32.

FIG. 11b shows the result of a crossover from Geographic Data Block 22 to Geographic Data Block 32.

FIG. 12a through FIG. 12e, and FIG. 13a through FIG. 13e show the procedure for generating the polygon data base from the Digital Elevation Model data.

DETAILED SPECIFICATION

FIG. 1 shows the basic form of the invention. GPS Receiver 101 receives signals from the satellites that make up the global positioning system (GPS) and calculates the aircraft's position in three dimensions. Altimeter 104 provides an output of the aircraft's altitude as a safety check in the event GPS Receiver 101 malfunctions. Turn-and-bank Indicator 102 and Gyrocompass 103 provide the aircraft's attitude which comprises heading, roll, and pitch. CD-ROM Data Base 105 contains the digital data base consisting of three-dimensional polygon data for terrain and manmade structures.

Computer 107 is shown in more detail in FIG. 4 and uses commercially available integrated circuits including processor 404, the MPC601, from Motorola Semiconductor Inc. The MPC601 is a fast 32-bit RISC processor with a floating point unit and a 32K Byte eight-way set-associative unified instruction and data cache. Most integer instructions are executed in one clock cycle. Compilers are available for ANSI standard C and for ANSI standard FORTRAN 77. Computer 107 also contains ROM 405, RAM 406, Avionics Interface 401, CD-ROM Interface 402, Control Panel Interface 403, Graphics Systems Interface 407, and Hard Drive Interface 408.

Computer 107 uses the aircraft's position from GPS Receiver 101 to look up the terrain and manmade structure data in CD-ROM Data Base 105. This data is organized in geographic blocks and is accessed so that there is always the proper data present. This is shown in FIG. 10a. FIG. 10b shows that when the aircraft crosses from Block 21 to Block 22, the data from Blocks 10, 20, and 30 are discarded and data from Blocks 13, 23, and 33 are brought in from CD-ROM Data Base 105. FIG. 11a and FIG. 11b show the aircraft crossing from Block 22 to Block 32.

Computer 107 uses the aircraft's position from GPS Receiver 101 and attitude information from Turn-and-bank Indicator 102 and Gyrocompass 103 to mathematically operate on the terrain and manmade structure data to present three-dimensional projected polygons to Graphics System 108. As shown in FIG. 4, Graphics System 108 consists of a commercially available graphics integrated circuit 409, the 86C805, made by S3 Incorporated. This integrated circuit contains primitives for drawing lines in addition to the standard SVGA graphics functions. The 86C805 controls DRAM 410 which is the video memory consisting of two buffers of 1024 x 768 pixels, each of which is 8 bits deep. The video to be displayed from DRAM 410 is sent to RAMDAC 411 which is an integrated circuit commercially available from several manufacturers, such as Brooktree and AT&T. RAMDAC 411 contains a small RAM of 256 x 24 bits and three 8-bit DACs. The RAM section is a color table programmed to assign the desired color to each of the 256 combinations possible by having 8 bits/pixel and is combined with three video DACs, one for each color for Video Display 109.

Video Display 109 is a color video display of conventional design such as a standard CRT, an LCD panel, or a plasma display panel. The preferred size of Video Display 109 is 19" although other sizes may be used.

FIG. 2 shows the use of the system with Head Mounted Display 201. Head Mounted Display Attitude Sensors 202 provide Computer 107 with the orientation of Head Mounted Display 201. This orientation is concatenated with the aircraft's orientation provided by Turn-and-bank Indicator 102 and Gyrocompass 103. As a consequence the pilot can turn his or her head and view the three-dimensional synthesized view of the transformed terrain and manmade structure data unhindered by the aircraft's structure. With the appropriate sensors for engines, fuel tanks, doors, and the like, the pilot can be presented with synthesized representations of these objects in their correct locations. For example, the pilot would be able to 'look' at a fuel tank and 'see' if it is running low. The pilot would also be able to 'see' if there is a problem with an engine and, on multi-engine aircraft, identify which one. By using a technique similar to that taught in the 1992 patent to Fraughton et al. (U.S. Patent No. 5,153,836) where each aircraft determines its own position using LORAN or GPS and transmits it on a radio channel along with the aircraft's identification information so that each craft also receives the radio channel and can thereby determine the position and identification of other craft in the vicinity, these other aircraft can be presented in the present invention as three-dimensional objects in their correct positions to alert the pilot to their presence and take evasive maneuvers as required.

Hard Disk Drive 110 is for recording the aircraft's position and orientation data for later playback in order to review the flight. Because the information presented on Video Display 109 is a function of the aircraft's position and orientation data applied to the CD-ROM Data Base 105, it can be reconstructed later at any time by storing just the aircraft's position and orientation data and applying it again to CD-ROM Data Base 106, as long as the data base is still available. The aircraft's position and orientation data requires fewer than 100 bytes. By recording it every 0.1 seconds, an hour requires about 3.6 Megabytes of storage. (100 bytes/update x 10 updates/second x 60 seconds/min x 60 minutes/hour = about 3.6 Megabytes) Therefore, a standard 340 Megabyte hard drive would store about 94 hours of operation.

A method for previewing a route that has not been flown before is shown in FIG. 3 . GPS Receiver 101, Turn-and-bank Indicator 102, Gyrocompass 103, and Altimeter 104 are replaced by User Flight Controls with Force Feedback 301 and Aerodynamic Model Processor 302. Aerodynamic Model Processor 302 is a processor that implements the aerodynamic mathematical model for the type of aircraft desired. It receives the user inputs from User Flight Control with Force Feedback 301, performs the mathematical calculations to simulate the desired aircraft, and supplies output back to the Force Feedback part of

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the controls and to Computer 107. The outputs supplied to Computer 107 simulate the outputs normally supplied to GPS Receiver 101, Turn-and-bank Indicator 102, Gyrocompass 103, and Altimeter 104. In this way, Computer 107 executes exactly the same program that it would perform in the in-flight system. This permits the pilot to practice flying routes that he or she has not flown before and is particularly useful in practicing approach and landing at unfamiliar airports. This system does not need to be installed in an aircraft; it can be installed in any convenient location, even the pilot's home.

Control Panel ~~104~~ 106 allows the pilot to select different operating features. For example, the pilot can choose the 'look angle' of the display (pan and tilt). This would allow the pilot to see synthesized terrain coresponding to real terrain that would otherwise be blocked by the aircraft's structure like the nose, or the wing on a low wing aircraft. Another feature is the zoom function which provides magnification. Another feature is to permit the pilot to select a section of the route other than the one he or she is on, for example, to preview the approach to the destination airport.

MATH INTRO

The math for the present invention has been used in the field of coin-operated video games and in traditional computer graphics. However, since it has not been well documented, it will be presented here. The basic concept assumes the unit is a simulator, responsive to ~~the~~ the user's inputs. It is a short step from that to the present invention where the inputs represent the physical location and attitude of the aircraft.

The steps required to view a 3D polygon-based data base are:

1. Transformation (translation and rotation as required)
2. Visibility and illumination
3. Clipping
4. Projection

In this geometric model there is an absolute Universe filled with Objects, each of which is free to rotate and translate. Associated with each Object is an Orthonormal Matrix (i.e. a set of Orthogonal Unit Vectors) that decribes the Object's orientation with respect to the Universe. Because the Unit Vectors are Orthogonal, the Inverse of the matrix is simply the Transpose. This makes it very easy to change the point of reference. The Object may look at the Universe or the Universe may look at the Object. The Object may look at another Object after the appropriate concatenation of Unit Vectors. Each Object will always Roll, Pitch, or Yaw around its own axes regardless of its current orientation without using Euler angle functions.

ROTATIONS

The convention used here is that the Z axis is straight up, the X axis is straight ahead, and the Y axis is to the right. ROLL is a rotation around the X axis, PITCH is a rotation around the Y axis, and YAW is a rotation around the Z axis.

For a simple positive (counter-clockwise) rotation of a point around the origin of a 2-Dimensional space:

```
X'= X*COS(a) - Y*SIN(a)
Y'= X*SIN(a) + Y*COS(a)
```

See FIG. 5a.

If we want to rotate the point again there are two choices:

1. Simply sum the angles and rotate the original points, in which case:

```
X" = X*COS(a+b) - Y*SIN(a+b)
Y" = X*SIN(a+b) + Y*COS(a+b)
```

2. Rotate X', Y' by angle b:

```
X" = X'*COS(b) - Y'*SIN(b)
Y" = X'*SIN(b) + Y'*COS(b)
```

See FIG. 5b.

With the second method the errors are cumulative. The first method preserves the accuracy of the original coordinates; unfortunately it works only for rotations around a single axis. When a series of rotations are done together around two or three axes, the order of rotation makes a difference. As an example: An airplane always Rolls, Pitches, and Yaws according to its own axes. Visualize an airplane suspended in air, wings straight and level, nose pointed North. Roll 90 degrees clockwise, then pitch 90 degrees "up". The nose will be pointing East. Now we will start over and reverse the order of rotation. Start from straight and level, pointing North. Pitch up 90 degrees, then Roll 90 degrees clockwise, The nose will now be pointing straight up, where "up" is referenced to the ground. If you have trouble visualizing these motions, just pretend your hand is the airplane.

This means that we cannot simply keep a running sum of the angles for each axis. The standard method is to use functions of Euler angles. The method to be described is easier and faster to use than Euler angle functions.

Although FIG. 5a represents a two dimensional space, it is equivalent to a three dimensional space where the rotation is around the Z axis. See FIG. 6a. The equations are :

```
X' = X*COS(za) - Y*SIN(za)          Equation 1
Y' = X*SIN(za) + Y*COS(za)
```

By symmetry the other equations are:

```
Z' = Z*COS(ya) - X*SIN(ya)          Equation 2
X' = Z*SIN(ya) + X*COS(ya)
```

See FIG. 6b.

and

```
Y' = Y*COS(xa) - Z*SIN(xa)          Equation 3
Z' = Y*SIN(xa) + Z*COS(xa)
```

See FIG. 6c.

From the ship's frame of reference it is at rest; it is the Universe that is rotating. We can either change the equations to make the angles negative or decide that positive rotations are clockwise. Therefore, from now on all positive rotations are clockwise.

Consolidating Equations 1, 2, and 3 for a motion consisting of rotations za (around the Z axis), ya (around the Y axis), and xa (around the X axis) yields:

```
X' =   X*[COS(ya)*COS(za)]                                   +
       Y*[-COS(ya)*SIN(za)]                                  +
       Z*[SIN(ya)]
Y' =   X*[SIN(xa)*SIN(ya)*COS(za)+COS(xa)*SIN(za)]           +
       Y*[-SIN(xa)*SIN(ya)*SIN(za) + COS(xa)*COS(za)]        +
       Z*[-SIN(xa)*COS(ya)]
Z' =   X*[-COS(xa)*SIN(ya)*COS(za) + SIN(xa)*SIN(za)]        +
       Y*[COS(xa)*SIN(ya)*SIN(za) + SIN(xa)*COS(za)]         +
       Z*[COS(xa)*COS(ya)]
```

(The asymmetry in the equations is another indication of the difference the order of rotation makes.)

The main use of the consolidated equations is to show that any rotation will be in the form:

```
X' = Ax * X + Bx * Y + Cx * Z
Y' = Ay * X + By * Y + Cy * Z
Z' = Az * X + Bz * Y + Cz * Z
```

If we start with three specific points in the initial, absolute coordinate system, such as:

```
Px = (1,0,0)
Py = (0,1,0)
Pz = (0,0,1)
```

after any number of arbitrary rotations,

```
Px' = (XA,YA,ZA)
Py' = (XB,YB,ZB)
Pz' = (XC,YC,ZC)
```

By inspection:

XA=Ax	XB=Bx	XC=Cx
YA=Ay	YB=By	YC=Cy
ZA=Az	ZB=Bz	ZC=Cz

Therefore, these three points in the ship's frame of reference provide the coefficients to transform the absolute coordinates of whatever is in the Universe of points. The absolute list of points is itself never changed so it is never lost and errors are not cumulative. All that is required is to calculate Px, Py, and Pz with sufficient accuracy.

Px, Py, and Pz can be thought of as the axes of a gyrocompass or 3-axis stabilized platform in the ship that is always oriented in the original, absolute coordinate system.

TRANSLATIONS

Translations do not affect any of the angles and therefore do not affect the rotation coefficients. Translations will be handled as follows:

Rather than keep track of where the origin of the absolute coordinate system is from the ship's point of view (it changes with the ship's orientation), the ship's location will be kept track of in the absolute coordinate system.

To do this requires finding the inverse transformation of the rotation matrix. Px, Py, and Pz are vectors, each with a length of 1.000, and each one orthogonal to the others. (Rotating them will not change these properties.) The inverse of an orthonormal matrix (one composed of orthogonal unit vectors like Px, Py, and Pz) is formed by transposing rows and columns.

Therefore, for X, Y, Z in the Universe's reference and X', Y', Z' in the Ship's reference:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} Ax & Ay & Az \\ Bx & By & Bz \\ Cx & Cy & Cz \end{bmatrix} * \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

The ship's X unit vector (1,0,0), the vector which, according to the ship is straight ahead, transforms to (Ax,Bx,Cx). Thus the position of the ship in terms of the Universe's coordinates can be determined.

The complete transformation for the Ship to look at the Universe, taking into account the position of the Ship:

For X,Y,Z in Universe reference and X', Y', Z' in Ship's reference

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X-XT \\ Y-YT \\ Z-ZT \end{bmatrix}$$

INDEPENDENT OBJECTS

To draw objects in a polygon-based system, rotating the vertices that define the polygon will rotate the polygon.

The object will be defined in its own coordinate system (the object "library") and have associated with it a set of unit vectors. The object is rotated by rotating its unit vectors. The object will also have a position in the absolute Universe.

When we want to look at an object from any frame of reference we will transform each point in the object's library by applying a rotation matrix to place the object in the proper orientation. We will then apply a translation vector to place the object in the proper position. The rotation matrix is derived from both the object's and the observer's unit vectors; the translation vector is derived from the object's position, the observer's position, and the observer's unit vectors.

The simplest frame of reference from which to view an object is in the Universe's reference at (0,0,0) looking along the X axis. The reason is that we already have the rotation coeficients to look at the object. The object's unit vectors supply the matrix coefficients for the object to look at (rotate) the Universe. The inverse of this matrix will allow the Universe to look at (rotate) the object. As discussed previously, the unit vectors form an Orthonormal matrix; its inverse is simply the Transpose. After the object is rotated, it is translated to its position (its position according to the Universe) and projected. More on projection later.

A consequence of using the Unit Vector method is that, whatever orientation the object is in, it will always Roll, Pitch, and Yaw according to ITS axes.

For an object with unit vectors:

$$\begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix}$$

and absolute position [XT,YT,ZT], and [X,Y,Z] a point from the object's library, and [X',Y',Z'] in the Universe's reference,

The Universe looks at the object:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Ay & Az \\ Bx & By & Bz \\ Cx & Cy & Cz \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix}$$

For two ships, each with unit vectors and positions:

$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix}$	Ship 1 Unit Vectors
(XT1,YT1,ZT1)	Ship 1 Position
$\begin{bmatrix} Ax2 & Bx2 & Cx2 \\ Ay2 & By2 & Cy2 \\ Az2 & Bz2 & Cz2 \end{bmatrix}$	Ship 2 Unit Vectors
(XT2,YT2,ZT2)	Ship 2 Position
$\begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix}$	Transpose (Inverse) of Ship 2 Unit Vectors

(X,Y,Z) in Ship 2 library, (X',Y',Z') in Universe Reference, and (X",Y",Z") in Ship 1 Reference

Universe looks at ship 2:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix}$$

Ship 1 looks at the Universe looking at Ship 2:

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} X' - XT1 \\ Y' - YT1 \\ Z' - ZT1 \end{bmatrix}$$

$$= \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} - \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT1 \\ YT1 \\ ZT1 \end{bmatrix} \qquad \text{EQUATION 10}$$

Expand:

$$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \left(\begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix} \right)$$

Using the Distributive Law of Matrices:

$$= \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \left(\begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \right) + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix}$$

Using the Associative Law of Matrices:

$$= \left(\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \right) * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix}$$

Substituting back into Equation 10 gives:

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \left(\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix} \right) * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT2 \\ YT2 \\ ZT2 \end{bmatrix} - \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT1 \\ YT1 \\ ZT1 \end{bmatrix}$$

Therefore:

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \left(\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} AX2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ CX2 & Cy2 & Cz2 \end{bmatrix} \right) * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT2-XT1 \\ YT2-YT1 \\ ZT2-ZT1 \end{bmatrix}$$

EQUATION 11

Now let:

$$\begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Bz2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix}$$

EQUATION 12

This matrix represents the orientation of Ship 2 according to Ship 1's frame of reference. This concatentation needs to be done only once per update of Ship 2.

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Also let:

$$\begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT2-XT1 \\ YT2-YT1 \\ ZT2-ZT1 \end{bmatrix} \qquad \text{EQUATION 13}$$

(XT,YT,ZT) is merely the position of Ship 2 in Ship 1's frame of reference.

This also needs to be done only once per update of Ship 2. Therefore the transformation to be applied to Ship 2's library will be of the form:

$$\begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix} \qquad \text{EQUATION 14}$$

Therefore, every object has six degrees of freedom, and any object may look at any other object.

SUMMARY OF TRANSFORMATION ALGORITHMS:

```
Define Unit Vectors:  [Px] = (Ax,Ay,Az)

                      [Py] = (Bx,By,Bz)

                      [Pz] = (Cx,Cy,Cz)

Initialize: Ax=By=Cz=1.000
            Ay=Az=Bx=Bz=Cx=Cy=0

If Roll:
          Ay' = Ay*COS(xa) - Az*SIN(xa)
          Az' = Ay*SIN(xa) + Az*COS(xa)

          By' = By*COS(xa) - Bz*SIN(xa)
          Bz' = By*SIN(xa) + Bz*COS(xa)

          Cy' = Cy*COS(xa) - Cz*SIN(xa)
          Cz' = Cy*SIN(xa) + Cz*COS(xa)

If Pitch:

          Az' = Az*COS(ya) - Ax*SIN(ya)
          Ax' = Az*SIN(ya) + Ax*COS(ya)

          Bz' = Bz*COS(ya) - Bx*SIN(ya)
          Bx' = Bz*SIN(ya) + Bx*SIN(ya)

          Cz' = Cz*COS(ya) - Cx*SIN(ya)
          Cx' = Cz*SIN(ya) + Cx*COS(ya)
```

If Yaw:

```
Ax' = Ax*COS(za) - Ay*SIN(za)
Ay' = Ax*SIN(za) + Ay*COS(za)

Bx' = Bx*COS(za) - By*SIN(za)
By' = Bx*SIN(za) + By*COS(za)

Cx' = Cx*COS(za) - Cy*SIN(za)
Cy' = Cx*SIN(za) + Cy*COS(za)
```

('za', 'ya', and 'xa' are incremental rotations.)

The resultant unit vectors form a transformation matrix. For X, Y, Z in Universe reference and X', Y', Z' in Ship's reference

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

and

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} Ax & Ay & Az \\ Bx & By & Bz \\ Cx & Cy & Cz \end{bmatrix} * \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

The ship's x unit vector, the vector which according to the ship is straight ahead, transforms to (Ax,Bx,Cx). For a ship in free space, this is the acceleration vector when there is forward thrust. The sum of the accelerations determine the velocity vector and the sum of the velocity vectors determine the position vector (XT,YT,ZT).

For two ships, each with unit vectors and positions:

$$\begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix}$$ Ship 1 Unit Vectors

(XT1,YT1,ZT1) Ship 1 Position

$$\begin{bmatrix} Ax2 & Bx2 & Cx2 \\ Ay2 & By2 & Cy2 \\ Az2 & Bz2 & Cz2 \end{bmatrix}$$ Ship 2 Unit Vectors

(XT2,YT2,ZT2) Ship 2 Position

Ship 1 looks at the Universe:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} X-XT \\ Y-YT \\ Z-ZT \end{bmatrix}$$

(X,Y,Z) in Universe
(X',Y',Z') in Ship 1 frame of reference

Ship 1 looks at Ship 2:

$$\begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} Ax2 & Ay2 & Az2 \\ Bx2 & By2 & Cy2 \\ Cx2 & Cy2 & Cz2 \end{bmatrix}$$

(Ship 2 orientation relative to Ship 1 orientation)

$$\begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix} = \begin{bmatrix} Ax1 & Bx1 & Cx1 \\ Ay1 & By1 & Cy1 \\ Az1 & Bz1 & Cz1 \end{bmatrix} * \begin{bmatrix} XT2-XT1 \\ YT2-YT1 \\ ZT2-ZT1 \end{bmatrix}$$

(Ship 2 position in Ship 1's frame of reference)

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} Ax & Bx & Cx \\ Ay & By & Cy \\ Az & Bz & Cz \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} XT \\ YT \\ ZT \end{bmatrix}$$

(X,Y,Z) in Ship 2 library
(X',Y',Z') in Ship 1 reference

VISIBILITY AND ILLUMINATION

After a polygon is transformed, whether it is a terrain polygon or it belongs to an independently moving object such as another aircraft, the next step is to determine its illumination value, if indeed, it is visible at all.

Associated with each polygon is a vector of length 1 that is normal to the surface of the polygon. This is obtained by using the vector crossproduct between the vectors forming any two adjacent sides of the polygon. For two vectors V1 = [x1,y1,z1] and V2 = [x2,y2,z2] the crossproduct V1 X V2 is the vector [(y1*z2-y2*z1),-(x1*z2-x2*z1),(x1*y2-x2*y1)]. The vector is then normalized by dividing it by its length. This gives it a length of 1. This

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calculation can be done when the data base is generated, becoming part of the data base, or it can be done during program run time. The tradeoff is between data base size and program execution time. In any event, it becomes part of the transformed data.

After the polygon and its normal are transformed to the aircraft's frame of reference, we need to calculate the angle between the polygon's normal and the vector from the base of the normal to the aircraft. This is done by taking the vector dot product. For two vectors V1 = [x1,y1,z1] and V2 = [x2,y2,z2], V1 dot V2 = length(V1) * length(V2) * cos(a) and is calulated as (x1*x2 + y1*y2 + z1*z2). Therefore:

$$\cos(a) = \frac{(x1*x2 + y1*y2 + z1*z2)}{\text{length}(V1) * \text{length}(V2)}$$

A cosine that is negative means that the angle is between 90 degress and 270 degrees. Since this angle is facing away from the observer it will not be visible and can be rejected and not subjected to further processing. The actual cosine value can be used to determine the brightness of the polygon for added realism.

CLIPPING

Now that the polygon has been transformed and checked for visibility it must be clipped so that it will properly fit on the screen after it is projected. Standard clipping routines are well known in the computer graphics industry. There are six clipping planes as shown in the 3D representation shown in FIG. 8a . The 2D top view is shown in FIG. 8b, and the 2D side view is shown in FIG. 8c. It should be noted that clipping a polygon may result in the creation of addition polygon sides which must be added to the polygon description sent to the polygon display routine.

PROJECTION

As shown in FIG. 7a, X' is the distance to the point along the X axis, Z' is the height of the point, Xs is the distance from the eyepoint to the screen onto which the point is to be projected, and Sy is the vertical displacement on the screen. Z'/X' and Sy/Xs form similar triangles so: Z'/X' = Sy/Xs , therefore Sy = Xs*Z'/X' . Likewise, Y'/X' = Sx/Xs so Sx = Xs*Y'/X' where Sx is the horizontal displacement on the screen. However, we still need to fit Sy and Sx to the monitor display coordinates. Suppose we have a screen that is 1024 by 1024. Each axis would be plus or minus 512 with (0,0) in the center. If we want a 90 degree field of view (plus or minus 45 degrees from the center), then when a point has Z'/X'=1 it must be put at the edge of the screen where its value is 512. Therefore Sy = 512*Z'/X'. (Sy is the Screen Y-coordinate).

Therefore:

Sy = K*Z'/X'   Sy is the vertical coordinate on the display

Sx = K*Y'/X'   Sx is the horizontal coordinate on the display

K is chosen to make the viewing angle fit the monitor coordinates. If K is varied dynamically we end up with a zoom lens effect. And if we are clever in implementing the divider, K can be performed without having to actually do a multiplication.

THE DATABASE

The data base is generated from several sources. The U.S. Geological ~~Service~~ Survey (USGS) makes available various databases, two of which are of particular interest. The first is the Digital Elevation Model data which consist of an array of regularly spaced terrain elevations. This data base is converted into a data base containing polygons (whose vertices are three-dimensional points) in order to maximize the geographic area covered by CD-ROM Data Base 105 and also to reduce the amount of run-time processing required of Computer 107. This is possible because there are large areas of terrain that are essentially flat. Note that flat does not necessarily mean level. A sloping area is flat without being level.

The Digital Elevation Model data elevations are spaced 30 meters apart. 30 meters = 30m x 39.37in/m x 1ft/12 in = 98.245 ft . A linear mile contains 5,280 ft/mi x 1 data point/98.245 ft = 53.65 data points/mi . Therefore, a square mile contains 53.65 x 53.65 = 2878 data points. California has a total area of 158,706 square miles which requires 158,706 x 2878 = 456,755,868 data points. Since this figure includes 2,407 sq mi of inland water areas, there are 2407 x 2878 = 6,927,346 data points just for inland water. The U.S. has a total area of 3,618,773 square miles which requires 3,618,773 x 2878 = 10,414,828,694 data points. This figure includes 79,484 sq mi of inland water areas requiring 79,484 x 2878 = 228,754,952 data points just for inland water.

The polygon data are organized in geographic data blocks. Because the amount of data in each geographic data block depends on the number of polygons and because the number of polygons depends on the flatness of the terrain, the size of each geographic data block is variable. Therefore, an address table is maintained that contains a pointer to each geographic data block. The first choice is to decide on the geographic area represented by the block. For the present invention the size is 20 mi x 20 mi = 400 sq mi . Therefore, the

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polygon data base for California requires 158,706 sq mi x 1 block/400 sq mi = 397 geographic data blocks. The number of polygons in a given geographic data block depends on the flatness of the terrain and what we decide is 'flat'. The definition of 'flatness' is that for a polygon whose vertices are three-dimensional points, there will be no elevation points that are higher than the plane of the polygon and there will be no elevation points that are below the the plane of the polygon by a distance called the Error Factor. A small Error Factor will require more polygons to represent a given terrain than will a large Error Factor. A small Error Factor will also generate the terrain more accurately. The Error Factor does not have to be the same for all Geographic Data Blocks. Blocks for areas of high interest, like airports and surrounding areas can be generated using a small Error Factor in order to represent the terrain more precisely. The present invention uses an Error Factor of 10 ft for areas surrounding airports and 50 ft for all other areas.

A procedure for generating the polygon data base from the Digital Elevation Model data is demonstrated in FIG. 12a through FIG. 12e and FIG. 13a through FIG. 13e. We start with three points which define a polygon and which has a surface. We select the next elevation point and decide if it belongs in the polygon accordinng to the citeria previously discussed. If it does, it gets added to the polygon. If not, not. We then test additional adjacent points until we run out. Then we start over with another three points.

When we are done generating polygons for a Geographic Data Block we go back and examine them; any polygon that is 'too big' is broken down into smaller polygons. This is to make sure there are always enough polygons on the screen to provide a proper reference for the pilot. (A single large polygon on the screen would not have any apparent motion.) Finally, the polygons are assigned colors and/or shades so that adjacent polygons will not blend into each other.

The other USGS data base used is the Digital Line Graph data which includes: political and administrative boundaries; hydrography consisting of all flowing water, standing water, and wetlands; major transportation systems consisting of roads and trails, railroads, pipelines, transmission lines, and airports; and significant manmade structures. The Digital Line Graph data is two-dimensional. In the present invention features such as water, roads, railroads, and pipelines are represented as polygons with elevations determined from the Digital Elevation Model data. Transmission lines and significant manmade structures are defined as three-dimensional objects made of polygons and are placed according to the elevations determined from the Digital Elevation Model data. The different types of objects are tagged so that by using Control Panel 106 the pilot can select them to be highlighted by category or by specific object. For example, the pilot can choose to have all airports highlighted or just the destination airport. The pilot can also choose to have a specific highway highlighted.

Data from additional digital data bases can also be incorporated. An example of such a data base is from Jeppesen Sanderson whose NavData Services division provides aeronautical charts and makes this information available in digital form.

While preferred embodiments of the present invention have been shown, it is to be expressly understood that modifications and changes may be made thereto and that the present invention is set forth in the following claims.

I claim:

1. A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining means for locating said aircraft's position in three dimensions;

a digital data base means containing polygon data representing terrain and manmade structures;

an attitude determining means for determining said aircraft's orientation in three dimensional space;

a control panel means for allowing said pilot to select different operating features;

a computer means for using said aircraft position data to access said terrain and manmade structure data from said digital data base and using said aircraft orientation data to transform said terrain and manmade structure data to provide three dimensional projected image data according to said operating features selected by said pilot;

a display means for displaying said three dimensional projected image data.

2. The position determining means of claim 1, wherein said position determining means comprises a standard system for receiving and processing data from the global positioning system.

3. The attitude determining means of claim 1, wherein said attitude determining means comprises a standard avionics system.

4. The digital data base of claim 1, wherein said digital data base means comprises a cd rom disc and cd rom drive.

5. The control panel means of claim 1, wherein said control panel means selects the functions of pan, tilt, and zoom.

6. The control panel means of claim 1, wherein said control panel means permits said pilot to preview the route ahead.

7. A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining means for locating said aircraft's position in three dimensions;

a digital data base means containing polygon data representing terrain and manmade structures;

an attitude determining means for determining said aircraft's orientation in three dimensional space;

a control panel means for allowing said pilot to select different operating features;

a computer means for using said aircraft position data to access said terrain and manmade structure data from said digital data base and using said aircraft orientation data to transform said terrain and manmade structure data to provide three dimensional projected image data according to said operating features selected by said pilot;

a display means for displaying said three dimensional projected image data;

a mass storage memory for recording said aircraft position data and said aircraft's attitude data for allowing said aircraft's flight to be displayed at a later time.

8. The position determining means of claim 7, wherein said position determining means comprises a standard system for receiving and processing data from the global positioning system.

9. The attitude determining means of claim 7, wherein said attitude determining means comprises a standard avionics system.

10. The digital data base of claim 7, wherein said digital data base means comprises a cd rom and cd rom drive.

11. The control panel means of claim 7, wherein said control panel means selects the functions of pan, tilt, and zoom.

12. The control panel means of claim 7, wherein said control panel means permits said pilot to preview the route ahead or to review previous flights.

13. A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining means for locating said aircraft's position in three dimensions;

a digital data base means containing polygon data representing terrain and manmade structures;

an attitude determining means for determining said aircraft's orientation in three dimensional space;

a head mounted display means worn by said pilot of said aircraft;

an attitude determining means for determining the orientation of said pilot's head in three dimensional space;

a control panel means for allowing said pilot to select different operating features;

a computer means for using said aircraft position data to access said terrain and manmade structure data from said digital data base and using said aircraft orientation data and said pilot head orientation data to transform said terrain and manmade structure data to provide three dimensional projected image data to said head mounted display according to said operating features selected by said pilot.

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Declaration for Utility or Design Patent Application

As a below-named inventor, I hereby declare that my residence, post office address, and citizenship are as stated below next to my name and that I believe that I am the original, first, and sole inventor [if only one name is listed below] or an original, first, and joint inventor [if plural names are listed below] of the subject matter which is claimed and for which a patent is sought on the invention, the specification of which is attached hereto and which has the following title:

" PILOT AID USING SYNTHETIC REALITY "

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to in the oath or declaration. I acknowledge a duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, unter Title 18, United States Code, Section 1001, and that such willful false statements may jeopardize the validity of the application or any patent issues thereon.

Please send correspondance and make telephone calls to the First Inventor below.

Signature: Sole/First Inventor Jed Margolin

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Residence: San Jose, CA Citizen of: USA

Post Office Address: 3570 Pleasant Echo Dr.

San Jose, CA 95148-1916

Telephone: (408) 238-4564

Signature: Joint/Second Inventor ______

Print Name: ______ Date: ______

Residence: ______ Citizen of: ______

Post Office Address: ______

______

Telephone: ______

In the United States Patent and Trademark Office

First/Sole Applicant: Jed Margolin

Joint/Second Applicant: ______

Title: " PILOT AID USING SYNTHETIC REALITY "

Small Entity Declaration - Independent Inventor(s)

As a below-named inventor, I hereby declare that I quality as an independent inventor as defined in 37 CFR 1.9(c) for the purposes of paying reduced fees under Section 41(a) and (b) of Title 35 United States Code, to the Patent and Trademark Office with regard to my above-identified invention described in the specification filed herewith. I have not assigned, granted, conveyed, or licensed - and am under no obligation under any contract or law to assign, grant, convey, or license - any rights in the invention to either (a) any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention or (b) any concern which would not qualify as either (i) a small business concern under 37 CFR 1.9(d) or (ii) a nonprofit organization under 37 CFR 1.9(e).

Each person, concern, or organization to which I have assigned, granted, conveyed, or licensed - or am under an obligation under contract or law to assign, grant, convey, or license - any rights in the invention is listed below:

[✓] There is no such person, concern, or organization.

[ ] Any applicable person, concern, or organization is listed below:

Full Name: ______

Address: ______

I acknowledge a duty to file, in the above application for patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Jed Margolin
Signature of Sole/First Inventor

Signature of Joint/Second Inventor

Jed Margolin
Print Name of Sole/First Inventor

Print Name of Joint/Second Inventor

Date of Signature: 10 July 1994

Date of Signature: ______

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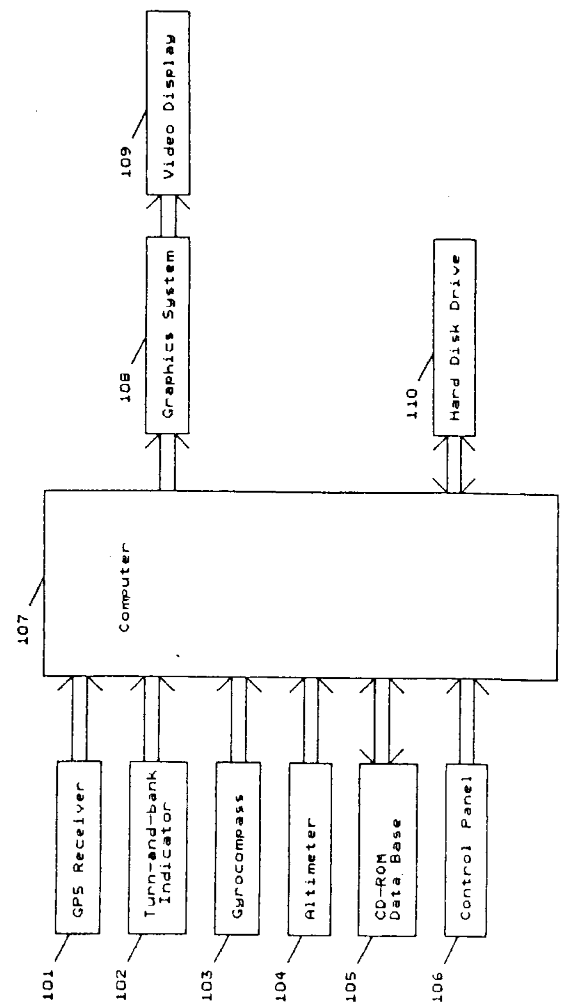

Fig. 1

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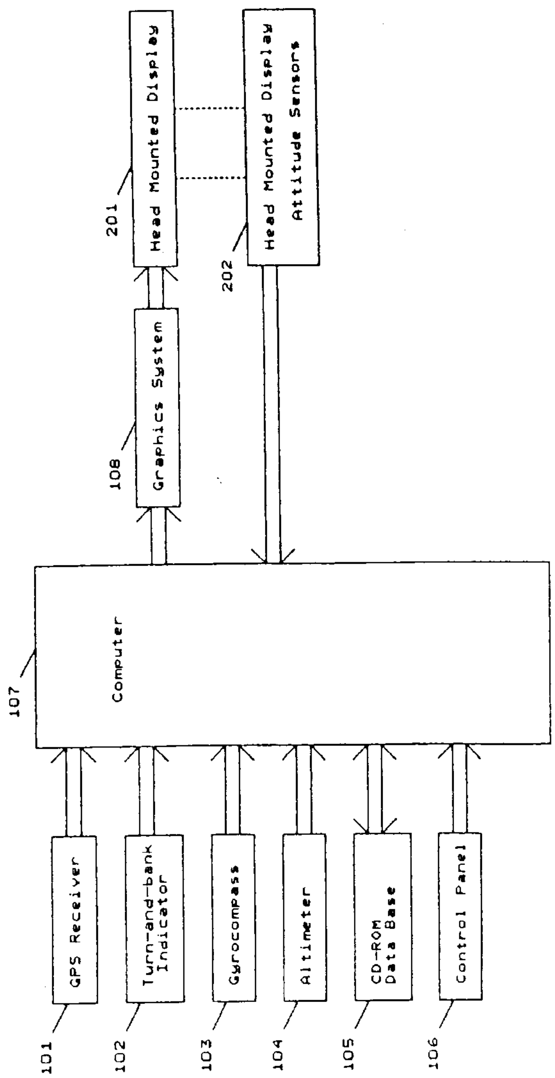
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Head Mounted Display
Attitude Sensors
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Graphics System
108
Computer
107
GPS Receiver
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Indicator
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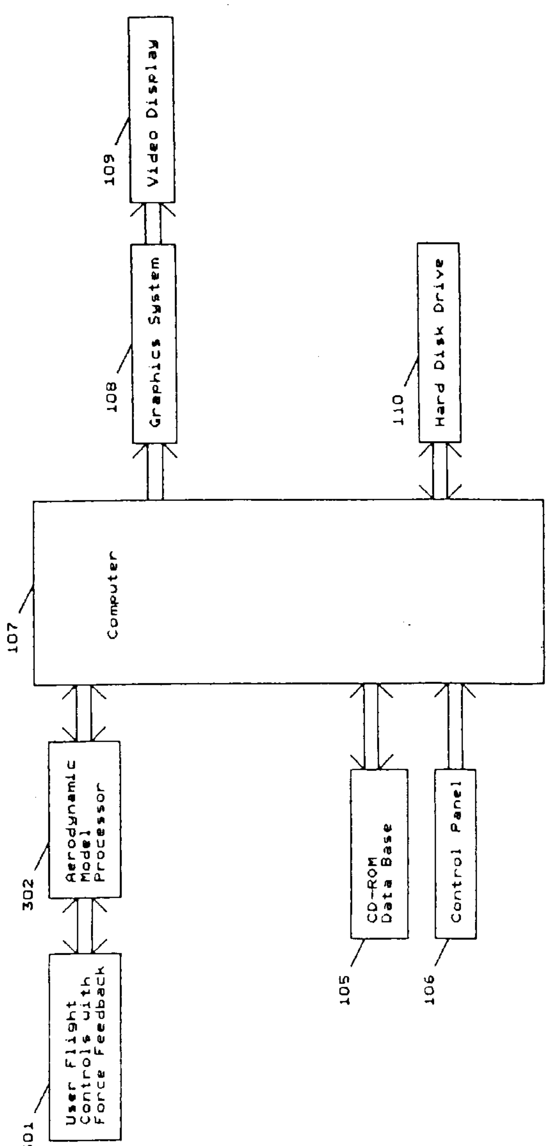
Gyrocompass
103
Altimeter
104
CD-ROM
Data Base
105
Control Panel
106

Fig. 2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Graphics System
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Computer
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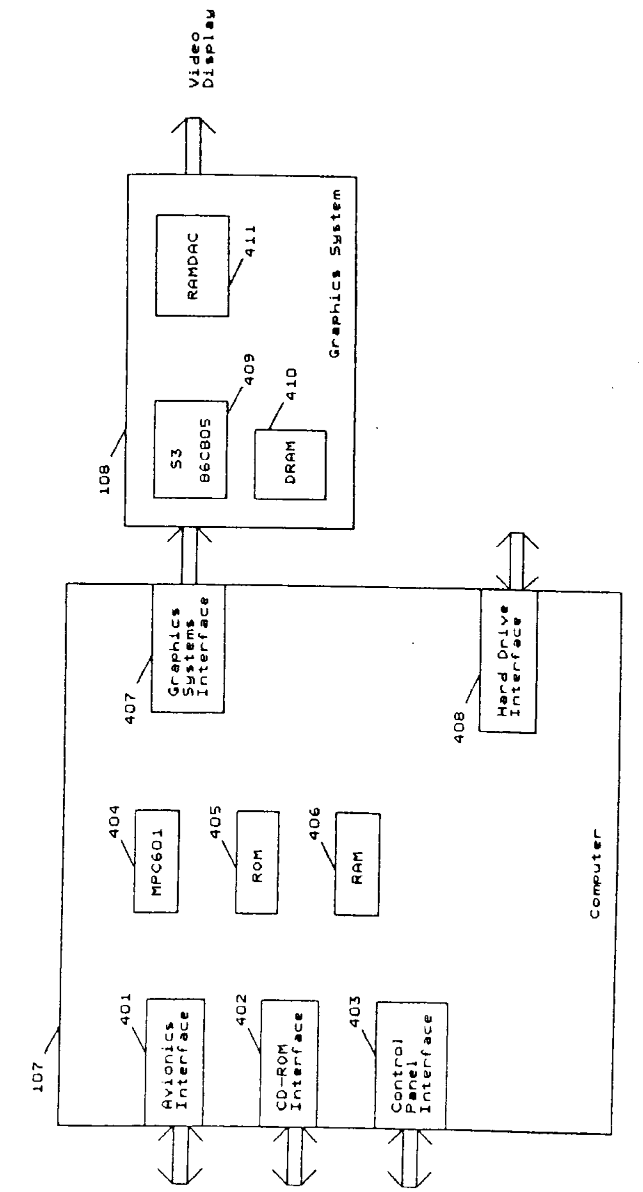
Aerodynamic Model Processor
302
User Flight Controls with Force Feedback
301
CD-ROM Data Base
105
Control Panel
106

Fig. 3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Graphics System
RAMDAC
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DRAM
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Graphics Systems Interface
407
Hard Drive Interface
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MPC601
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Computer
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CD-ROM Interface
402
Control Panel Interface
403
107

Fig. 4

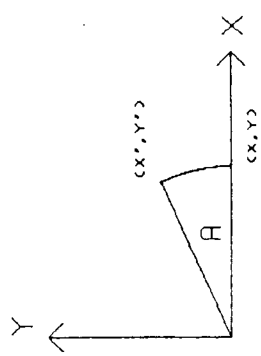

Fig. 5a

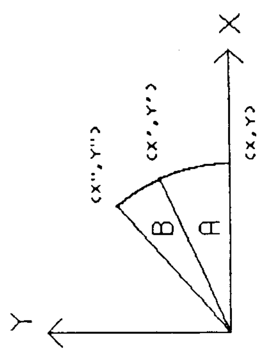

Fig. 5b

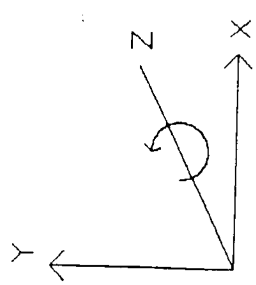

Fig. 6a

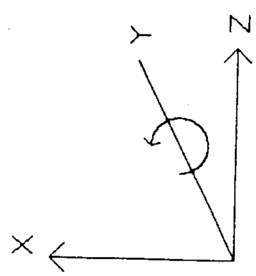

Fig. 6b

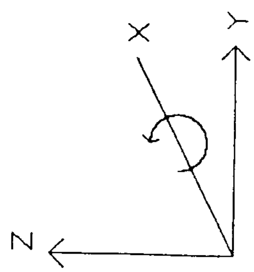

Fig. 6c

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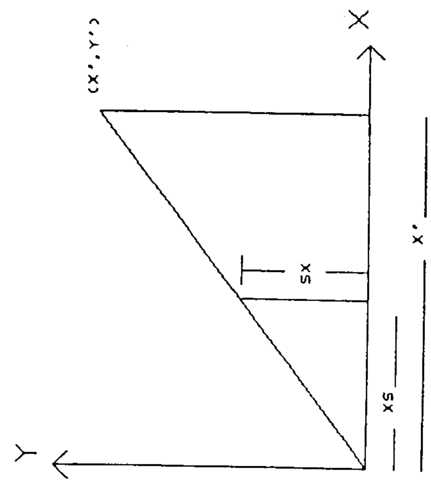

Fig. 7b Top

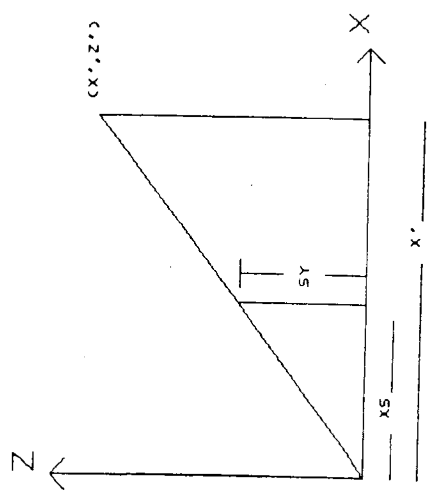

Fig. 7a Side

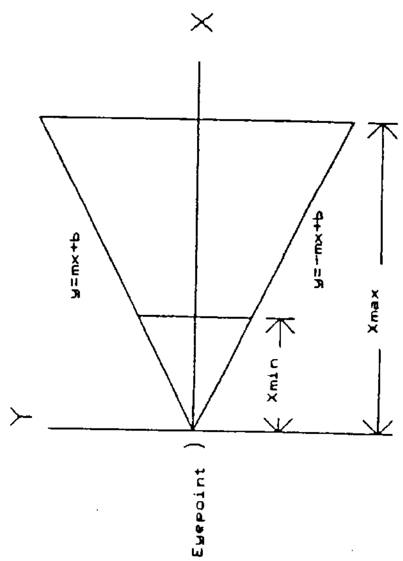

Fig. 8b Top View

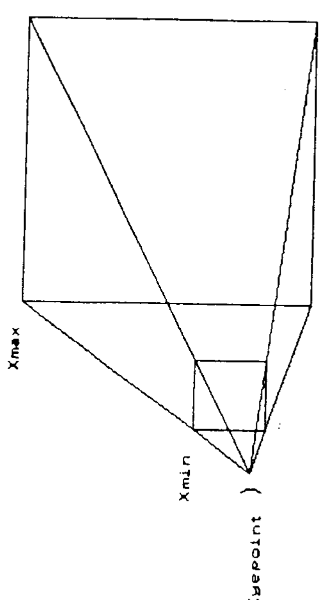

Fig. 8a

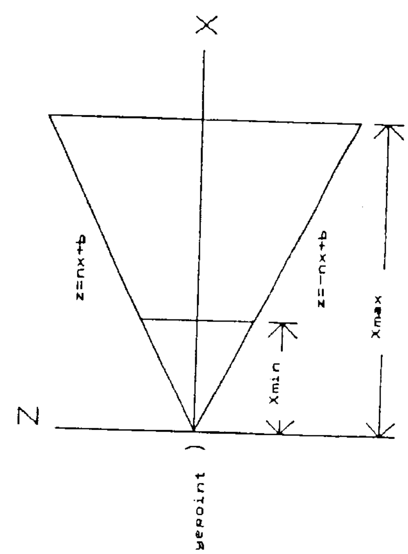

Fig. 8c Side View

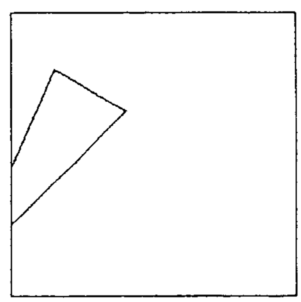

Fig. 9b

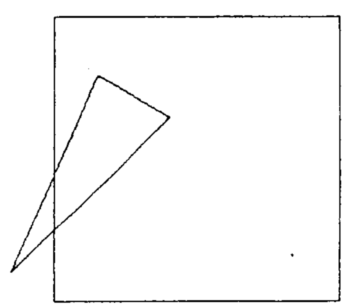

Fig. 9a

274394

12	22	32
11	← 21	31
1Ø	2Ø	3Ø

Fig. 1Øa

13	23	33
12	22 ←	32
11	21	31

Fig. 1Øb

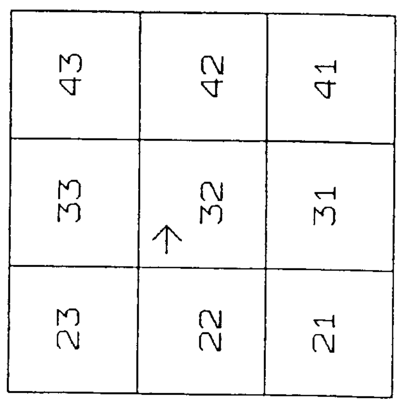

Fig. 11b

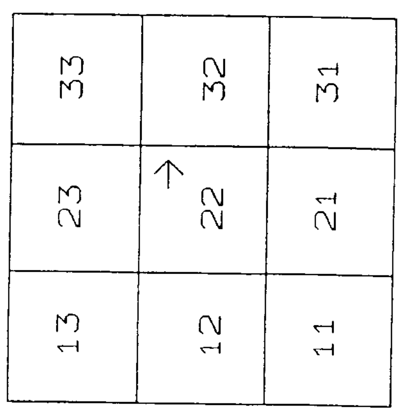

Fig. 11a

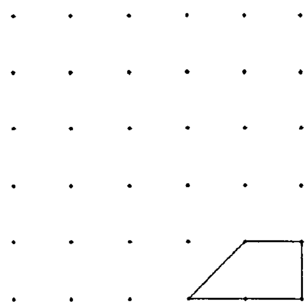

Fig. 12c

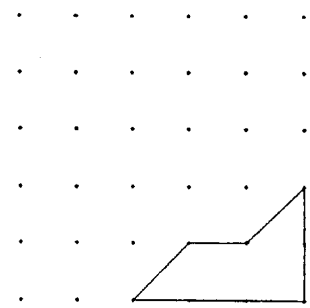

Fig. 12e

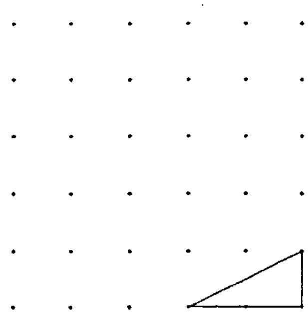

Fig. 12b

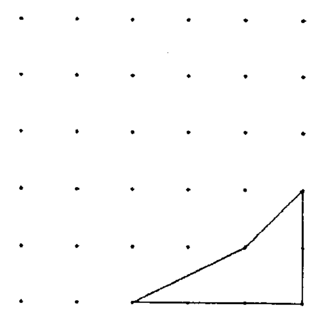

Fig. 12e

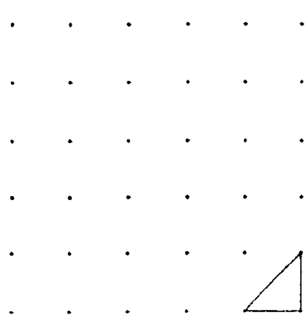

Fig. 12a

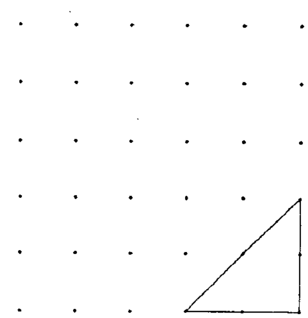

Fig. 12d

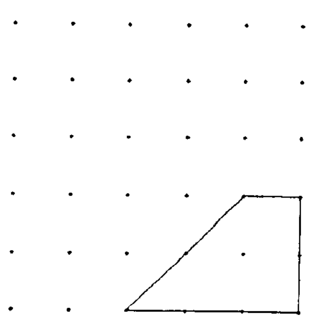
Fig. 13a

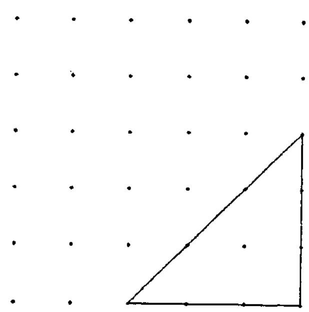
Fig. 13b

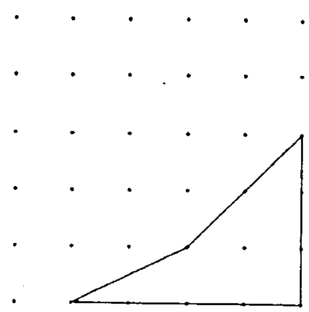
Fig. 13c

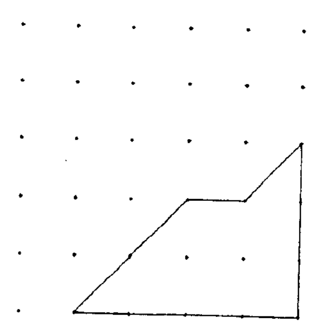
Fig. 13d

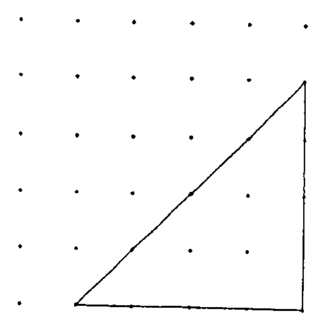
Fig. 13e

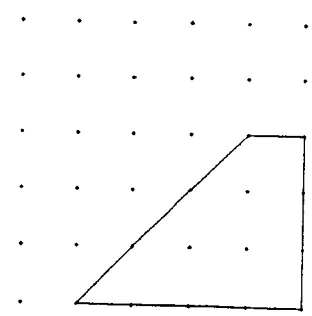
Fig. 13e

PATENT APPLICATION FEE DETERMINATION RECORD

Effective October 1, 1994

Application or Docket Number: 513 298

CLAIMS AS FILED - PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE	SMALL ENTITY FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY FEE
BASIC FEE				365.00	OR		730.00
TOTAL CLAIMS	37 minus 20 =	* 17	x$11=	187	OR	x$22=	
INDEPENDENT CLAIMS	4 minus 3 =	* 1	x38=	38	OR	x76=	
MULTIPLE DEPENDENT CLAIM PRESENT			+120=		OR	+240=	
			TOTAL	540	OR	TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2

CLAIMS AS AMENDED - PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x38=		OR	x76=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+120=		OR	+240=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x38=		OR	x76=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+120=		OR	+240=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x38=		OR	x76=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+120=		OR	+240=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Form PTO 1130
(REV 2-94)

PACE DATA ENTRY CODING SHEET

U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office

1ST EXAMINER sChapman DATE 9-13-95

2ND EXAMINER DATE

APPLICATION NUMBER	TYPE APPL	FILING DATE (MONTH DAY YEAR)	SPECIAL HANDLING	GROUP ART UNIT	CLASS	SHEETS OF DRAWINGS
08/513298	2	08 09 95	0	2304	364	13

TOTAL CLAIMS	INDEPENDENT CLAIMS	SMALL ENTITY?	FILING FEE	FOREIGN LICENSE	ATTORNEY DOCKET NUMBER
37	4	1	590	Y	02055.P002

CONTINUITY DATA

CONT CODE	STATUS CODE	PARENT APPLICATION SERIAL NUMBER	PCT APPLICATION SERIAL NUMBER	PARENT PATENT NUMBER	PARENT FILING DATE (MONTH DAY YEAR)
02	3	08274394	PCT / /		07 11 94
			PCT / /		
			PCT / /		
			PCT / /		
			PCT / /		

PCT/FOREIGN APPLICATION DATA

FOREIGN PRIORITY CLAIMED	COUNTRY CODE	PCT/FOREIGN APPLICATION SERIAL NUMBER	FOREIGN FILING DATE (MONTH DAY YEAR)

U.S. G.P.O. 1994-

01325

TITLE OF INVENTION

ATTORNEY DOCKET NUMBERS

CORRESPONDENCE NAME AND ADDRESS

APPLICANT/INVENTOR DATA

AUTHORITY CODE

FAMILY NAME

GIVEN NAME

CITY

NAME SUFFIX

STATE/CTRY CODE

AUTHORITY CODE

FAMILY NAME

GIVEN NAME

CITY

NAME SUFFIX

STATE/CTRY CODE

MORE

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570-2@1 08/511829

MAIL ROOM AUG 9 1995 PAT. & TRADEMARK OFC.

Attorney's Docket No. 02055.P002

Patent

12-1C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

The Commissioner of
Patents and Trademarks
Washington, D.C. 20231
BOX FWC

Prior Application:
Examiner: Nguyen, T.
Art Unit: 2304

RULE 62

Sir: This is a request for filing a **file wrapper**

_X_ Continuation application ___ Divisional application

under 37 C.F.R. § 1.62 of pending prior application serial no. 08/274,394

filed on July 11, 1994

of Jed Margolin

(inventor(s) currently of record for prior application)

for PILOT AID USING SYNTHETIC REALITY

(title)

_X_ 1. **The above-identified prior application in which no payment of the issue fee, abandonment of, or termination of proceedings has occurred is hereby expressly abandoned as of the filing date of this new application. Please use all the contents of the prior application file wrapper, including the drawings, as the basic papers for the new application. No such copy of the prior application is included herewith.**

_X_ 2. The filing fee is calculated below:

CLAIMS NOW PENDING IN THE PRIOR APPLICATION PLUS/MINUS CLAIMS ADDED/CANCELED BELOW

For:	(Col. 1) No. Filed		(Col. 2) No. Extra	SMALL ENTITY Rate	SMALL ENTITY Fee	OTHER THAN A SMALL ENTITY Rate	OTHER THAN A SMALL ENTITY Fee
Basic Fee:					$ 365		$ 730
Total Claims:	37	- 20	*17	x 11	$ 187	x 22	$
Indep. Claims:	4	- 3	* 1	x 38	$ 38	x 76	$
☐ Multiple Dependent Claim(s) Presented				+120	$	+240	$
				TOTAL	$ 590	TOTAL	$

* If the difference in Col. 1 is less than zero, enter "0" in Col. 2.

_X_ 3. A verified statement to establish small entity status under 37 C.F.R. §§ 1.9 and 1.27 ___ is enclosed/ _X_ was filed in the pending prior application **and such status is still proper and desired.** 37 C.F.R. § 1.28(a).

"Express Mail" mailing label number TB806948934US

Date of Deposit August 9, 1995

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Christine A. Bybee
(Typed or printed name of person mailing paper or fee)

Christine A. Bybee
(Signature of person mailing paper or fee)

LJV/wes/cak (10/01/94) Rule 62

01327

__X__ 4. The Commissioner is hereby authorized to charge any fees that may be required, or credit any overpayment, to Deposit Account No. 02-2666. A duplicate copy of this sheet is enclosed.

__X__ 5. A check in the amount of ____$590.00____ is enclosed for the filing fee.

______ 6. A check in the amount of $__________ is enclosed for the petition fee pursuant to 37 C.F.R. § 1.17.

______ 7. Cancel in this application claims _______________ of the prior application before calculating the filing fee (wherein at least one independent claim is retained for filing purposes).

______ 8. Please enter the preliminary amendment enclosed before calculating the filing fee.

______ 9. Before calculating the filing fee, please enter in the present application the amendment filed on _______________ under 37 C.F.R. § 1.116, but unentered, in the parent application.

__X__ 10. Amend the specification by inserting the following before the first sentence on the first page:

__X__ (a) – This is a __X__ continuation/______ divisional of application serial no. _08/274,394____, filed _July 11, 1994, now abandoned. –

______ (b) –, which is a ______ continuation/______ divisional of application serial no. __________, filed __________

(list all prior applications) –

__X__ 11. It is hereby requested that any request for a convention priority made in the prior application be transferred to this Rule 62 application.

______ 12. The prior application is assigned of record to:

__X__ 13. The Power of Attorney in the prior application is to:

(Name) (Reg. No.)

Edwin H Taylor, Reg. No. 25,129, and certain other listed attorneys or agent(s) of:
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN
12400 Wilshire Blvd., Seventh Floor
Los Angeles, California 90025
(310) 207-3800

______ (a) The Power appears in the original papers of the prior application serial no. __________ filed __________.

__X__ (b) The Power does not appear in the original papers, but was filed on _February 18, 1995_ in prior application serial no. _08/274/394_ filed _July 11, 1994_.

______ (c) A new Power has been executed and is attached.

______ (d) Recognize as an associate attorney or agent and address all future communications to:

(Name) (Reg. No.)

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN
12400 Wilshire Blvd., Seventh Floor
Los Angeles, California 90025
(408) 720-8598

______ (e) Address all future communications to the undersigned.

_____ **14. Enclosed is a photocopy of a petition for an extension of time pursuant to 37 C.F.R. § 1.136 concurrently (or previously) submitted under separate cover for the above-referenced prior application.**

__X__ 15. Applicant(s) hereby petition(s) for an extension of time pursuant to Rule 1.136, if needed, for the above-noted prior application. The Commissioner is hereby authorized to charge any extension or petition fee under 37 C.F.R. § 1.17 that may be required for the above-referenced prior application to Deposit Account No. 02-2666. Two photocopies of this document are enclosed for filing in the prior application file and for Deposit Account purposes.

__X__ 16. The filing of an application under 37 C.F.R § 1.62 will be construed to include a waiver of secrecy under 35 U.S.C. § 122 to the extent that any member of the public who is entitled under the provisions of 37 C.F.R. § 1.14 to access to or information concerning either the prior application or any continuing application filed under the provisions of 37 C.F.R. § 1.62 may be given similar access to, or similar information concerning, the other application(s) in the file wrapper. 37 C.F.R. § 1.62(f).

_____ 17. Accompanying this application is a statement requesting deletion of the name(s) of the person or persons who are not inventors of the invention being claimed in the continuation/divisional application. 37 C.F.R. § 1.62(a).

Respectfully submitted,

BLAKELY SOKOLOFF TAYLOR & ZAFMAN

Date: August 9, 1995

By [signature]
Keith G. Askoff

Reg. No. 33,828

12400 Wilshire Boulevard
Seventh Floor
Los Angeles, California 90025
(408) 720-8598

_____ Attorney or Agent of Record

__X__ Associate Attorney or Agent

_____ Filed Under 37 C.F.R. § 1.34(a)

MAIL ROOM JUL 14 1995 PAT. & TRADEMARK OFF.

002055.P002

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

DO NOT ENTER TA

In re Application of:

Jed Margolin

Serial No.: 08/274,394

Filed: July 11, 1994

For: PILOT AID USING SYNTHETIC REALITY

Examiner: T. Nguyen

Art Unit: 2304

RECEIVED AUG 1 1995 GROUP 2300

Commissioner of Patents and Trademarks
Washington, D.C. 20231

AMENDMENT AND RESPONSE

Dear Sir:

In response to the Office Action of May 9, 1995, please enter the following amendments and consider the following remarks.

IN THE CLAIMS

Please delete claims 29 - 30, without prejudice.

Please amend the following claims.

1. (Twice Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system for locating said aircraft's position in three dimensions;

a digital data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one [or more] polygon[s],said terrain data generated from elevation data of said real terrestrial terrain;

an attitude determining system for determining said aircraft's orientation in three dimensional space;

a computer to access said terrain data according to said aircraft's position and to transform said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and

a display for displaying said three dimensional projected image data.

---

5. (Twice Amended) The pilot aid of claim 1, further comprising a control panel to select at least one [or more] operating feature[s].

6. (Twice Amended) The pilot aid of claim [1] 5, wherein said at least one [or more] operating feature[s] comprises at least one [or more] feature[s] selected from [the] a group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, and providing a three dimensional projected image of a route ahead.

12 7. (Twice Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system for locating said aircraft's position in three dimensions;

a digital data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one [or more] polygon[s], said terrain data generated from elevation data of said real terrestrial terrain;

an attitude determining system for determining said aircraft's orientation in three dimensional space;

a computer to access said terrain data according to said aircraft's position and to transform said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and

a mass storage memory for recording said aircraft position data and said aircraft's attitude data for allowing a flight of said aircraft over said terrain to be displayed at a later time.

16 ~~11.~~ 21 (Twice Amended) The pilot aid of claim ~~7,~~ ~~17~~ 12 further comprising a control panel to select at least one [or more] operating feature[s].

17 ~~12.~~ ~~22~~ (Once Amended) The pilot aid of claim ~~11,~~ ~~21~~ 16 wherein said at least one [or more] operating feature[s] comprises at least one [or more] feature[s] selected from [the] a group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, providing a three dimensional projected image of a route ahead, and providing a three dimensional projected image of a previous flight.

23 ~~13.~~ ~~28~~ (Once Amended) A pilot aid which uses an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

a position determining system for locating said aircraft's position in three dimensions;

a digital data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one [or more] polygon[s], said terrain data generated from elevation data of said real terrestrial terrain;

a first attitude determining system for determining said aircraft's orientation in three dimensional space;

a head mounted display worn by said pilot of said aircraft;

a second attitude determining system for determining the orientation of said pilot's head in three dimensional space; and

a computer to access said terrain data according to said aircraft's position and to transform said terrain data to provide three dimensional projected image data to said head mounted display according to said aircraft's orientation and said pilot head orientation.

---

17. (Once Amended) The pilot aid as described in claim 1 wherein said [terrain data is generated from] elevation data [comprising] comprises an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by said at least one [or more of said] polygon[s no] each elevation point within each said polygon is [below] within a first distance of said plane of each said polygon [by a first distance or more].

18. (Once Amended) The pilot aid as described in claim 7 wherein said [terrain data is generated from] elevation data [comprising] comprises an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by said at least one [or more of said] polygon[s

no] each elevation point within each said polygon is [below] within a first distance of said plane of each said polygon [by a first distance or more].

19. (Once Amended) The pilot aid as described in claim 13 wherein said [terrain is generated from] elevation data [comprising] comprises an array of elevation points, wherein each said polygon representing said terrain defines a plane, wherein in a first region of terrain represented by said at least one [or more of said] polygon[s no] each elevation point within each said polygon is [below] within a first distance of said plane of each said polygon [by a first distance or more].

20. (Once Amended) The pilot aid as described in claim 17 wherein in a second region of said terrain represented by said at least one [or more of said] polygon[s no] each elevation point within each said polygon is [below] within a second distance of said plane of each said polygon in said second region [by a second distance or more], said second distance different from said first distance.

21. (Once Amended) The pilot aid as described in claim 18 wherein in a second region of said terrain represented by said at least one [or more of said] polygon[s no] each elevation point within each said polygon is [below] within a second distance of said plane of each said polygon in said second region [by a second distance or more], said second distance different from said first distance.

22. (Once Amended) The pilot aid as described in claim 19 wherein in a second region of said terrain represented by said at least one [or more of said] polygon[s no] each elevation point within each said polygon is [below] within a second distance of said plane of each said polygon in said second region [by a second distance or more], said second distance different from said first distance.

31. (Once Amended) The method as described in claim 23 wherein at least one [or more] additional adjacent one[s] of said plurality of elevation points [are] is examined, and wherein said polygon is expanded to include said at least one [or more] additional one[s] of said plurality of elevation points [which do] that does not cause any of said elevation points within said expanded polygon not to be [below] within said first distance of said plane of said expanded polygon [by said first distance or more].

32. (Once Amended) The method as described in claim 28 wherein at least one [or more] additional adjacent one[s] of said plurality of elevation points [are] is examined, and wherein said polygon is expanded to include said at least one [or more] additional one[s] of said plurality of elevation points [which do] that does not cause any of said elevation points within said expanded polygon to be above said plane of said expanded polygon and [do] does not cause any of said elevation points within said expanded polygon not to be [below] within said first distance of said plane of said expanded polygon [by said first distance or more].

36. (Once Amended) A method of using an aircraft's position and attitude to transform data from a digital data base to present a pilot with a synthesized three dimensional projected view of the world comprising:

locating said aircraft's position in three dimensions;

providing a data base comprising terrain data, said terrain data representing real terrestrial terrain as at least one [or more] polygons, said terrain data generated from elevation data of said real terrestrial terrain;

determining said aircraft's orientation in three dimensional space;

accessing said terrain data according to said aircraft's position;

transforming said terrain data to provide three dimensional projected image data according to said aircraft's orientation; and[,]

displaying said three dimensional projected image data.

~~37~~ 30. (Once Amended) The method of claim ~~36~~ 29 further comprising selecting at least one [or more] operating feature[s], wherein said at least one [or more] operating feature[s] comprises at least one [or more] feature[s] selected from [the] a group consisting of panning a viewpoint of said three dimensional projected image, tilting a viewpoint of said three dimensional projected image, zooming a viewpoint of said three dimensional projected image, and presenting a three dimensional projected image of a route ahead.

~~38~~ 31. (Once Amended) The method as described in claim ~~36~~ 29 wherein said terrain data base is produced by a method comprising the steps of:

providing a plurality of elevation points, each of said plurality of elevation points representing an elevation of a point on a terrain;

defining a polygon having at least one [or more vertices] vertex defined by at least one [or more] of said elevation points;

examining an adjacent one of said plurality of elevation points to determine if expanding said polygon to an expanded polygon to include said adjacent one of said plurality of elevation points causes at least one [or more] of said plurality of elevation points within said expanded polygon not to be [below] within a first distance of a plane of said expanded polygon [by a first distance]; and[,]

expanding said polygon to include said adjacent one of said plurality of elevation points if [none] each of said elevation points within said expanded polygon is [below] within said first distance of said plane [by said first distance or more].

37 ~~38~~. (Once Amended) The method as described in claim 31 ~~38~~ wherein said adjacent one of said plurality of elevation points is further examined to determine if at least one [or more] of said plurality of elevation points within said expanded polygon is above said plane of said expanded polygon, and said polygon is expanded if none of said elevation points within said expanded polygon is above said plane of said expanded polygon and if [none] each of said elevation points within said expanded polygon is [below] within said first distance of said plane ~~by~~ [said first distance or more].

REMARKS

In a telephonic interview on July 7, 1995 regarding the Office Action of May 9, 1995, the Examiner and the undersigned discussed some of the 35 U.S.C. § 112, second paragraph rejections, and the 35 U.S.C. § 103 rejections. In a telephonic interview of July 7, 1995 the Examiner and the undersigned discussed claims 17 and 20, which were not previously examined based on the prior art. The Examiner agreed to withdraw the finality of the Office Action of May 9, 1995.

With respect to the rejection under 35 U.S.C. § 112, second paragraph for the phrase "one or more" as described in paragraphs 4.1, 4.2, 4.3, 4.4, 4.5, and 4.8 of the Office Action, as discussed in the above-referenced telephonic interview, Applicant has amended the claims to recite "at least one" and to make grammatical changes consistent with the amended terminology.

With respect to the suggestion in paragraph 4.1 of the Office Action to add the word "and," Applicant has amended claims 1, 7, and 13 to add the word "and" at the appropriate place. With respect to antecedent basis for "the group" as in claims 6, 12, and 37, as noted in paragraph 4.3 of the Office Action, Applicant has amended claims containing this phrase to read "a group."

With respect to paragraph 4.4 of the Office Action of May 9, 1995 the Examiner requests verification of the first region of terrain. As described in the specification on, for example, page 30, lines 2 - 14, the number of polygons required to represent a portion of terrain will be dependent upon the definition of flatness (flatness criteria). If the elevation points within a polygon must be within a small distance from the plane of the polygon, more polygons will be required then when the elevation points may be within a greater distance of the plane of the polygon. As described in the specification, regions of high interest (such as airports and surrounding areas) may be represented with polygons having all points within a small distance from the plane of the polygon, while other areas may be represented by polygons having all elevation points within a larger distance from the plane of the polygon. Because the former regions will typically require more polygons, the terrain will be represented more accurately. Thus, for example, the airport may be a first region, while areas removed from the airport may be a second region.

With respect to the phrase "distance or more" in the claims discussed in paragraphs 4.4, 4.5, and 4.8 of the Office Action, Applicant has rephrased the claims. For example, claims 17 - 19 have been amended to recite that each elevation point within each polygon is within a first distance of the plane of the polygon. That is, for example, as described above, the elevation points within a first region, such as an airport, may be within 10 feet of the plane of the polygon. Of course, the invention is not limited to these examples. In claims 20 - 22, Applicant has recited that each elevation point within each polygon in the second region is within a second, different distance from the plane. Again, by way of example, in areas removed from the airport, the elevation points may be required to be within only 50 feet of the plane of the polygon. With respect to claims 31 and 32, Applicant has amended the claims to recite that the polygon is expanded to include the recited at least one addition one of the plurality of elevation points that does not cause any of the elevation points within the expanded polygon not to be within the first distance of the plane of the polygon. Similar amendments have been made to claims 38 and 39.

With regard to paragraph 4.6 of the Office Action of May 6, 1995, the Examiner requests clarification as to "no elevation point." As described generally above, a criteria may set such that a polygon contains no elevation points that are beyond a certain distance from the plane, or alternatively stated are not within a certain distance. In other words, in a polygon near an airport, no elevation point in the area represented by a polygon is above the plane of the polygon. In this way, a pilot may be ensured that in the real world scene represented by the polygons, no elevation point is above the level of the plane of the polygon.

With respect to paragraph 4.7 of the Office Action, Applicant has, as suggested, deleted the comma.

In paragraph 4.8 of the Office Action, the Examiner asks for verification regarding examining an adjacent one of the plurality of elevation points and expanding the polygon, as in lines 7 - 14 of claim 38. One embodiment of the method of the present invention is described, for example, in conjunction with figures 12A - 12F, and 13A - 13F of the specification. As shown therein, an initial polygon having three points is defined. Next, an adjacent elevation point is selected. A determination is made as to whether the point belongs in the polygon according to the above-discussed flatness criteria. If the expanded polygon meets the flatness criteria, the point is added, as shown in the Figures. If it does not, then the point is not added to the polygon.

Claims 1 - 12 were rejected under 35 U.S.C. § 103 as being unpatentable over *Beckwith et al.* in view of *Behensky et al.* or one of two brochures form *Atari Game Corporation*. In responding to Applicant's arguments, the Examiner states that Applicant's argument regarding the present invention representing real terrain is not found in the claims. Similarly, the Examiner states that constructing the polygon based on elevation points is not found in the claims. Applicant has amended all independent claims to include the limitations that the terrain data represents real terrestrial terrain and to recite that the terrain data is based on elevation data of the real terrestrial terrain. Applicant submits that these amendments clarify the distinction between the claimed invention and the references applied by the Examiner.

With respect to *Beckwith et al.*, Applicant submits that *Beckwith et al.* does not accurately perform a transformation of elevation points. Rather, *Beckwith et al.* uses a two-dimensional array of elevation points. The data address gives the x, y coordinates of the point, while the data gives the elevation. *Beckwith et al.* does not create a true 3-D scene. Rather, *Beckwith et al.* simply changes direction of data read out to correspond to the plane's orientation. This method creates a very crude representation of the terrain, particularly when, for example, the heading of the plane is not along a row, column, or diagonal of the data.

With reference to *Behensky et al.* and the *Atari brochures*, in contrast to the claimed invention, the references show a scene that consists of a completely made-up universe. In contrast to the claimed invention they do not show polygons based on elevation data of real terrestrial terrain. Furthermore, as described earlier, note that the display is significantly different from what is needed in the present invention. For example, features such as road markings, road signs, vehicles, etc. are present in these references, which are not applicable to the present invention as claimed. Note that the references, even when considered together, do not contain any motivation, either express or implied, that the depiction of the fictional universe therein be used for producing a display of real terrestrial data based on elevation data of the real terrestrial terrain. Furthermore, there is no teaching in the references of how this would be accomplished. Additionally, Applicant submits that it is not obvious that the polygons used for the fictional universe of *Behensky et al.* and the *Atari games* would be useful in the system of *Beckwith et al.* Although the Examiner states that it would be obvious to combine *Behensky et al.* with the systems of *Beckwith et al.* to provide a reduction of data base storage, there is no such teaching in the references. It is only with the teaching of the present invention, to construct the polygons in the manner described, and to use the described flatness criteria, that one of ordinary skill in the art is enabled to practice the present invention. Absent this teaching, nothing in the references teaches that the polygons of *Behensky et al.* would result in significant reduction of data base storage in other, undisclosed systems. Because there is no such teaching in the references, Applicant submits this assertion must be within the personal knowledge of the Examiner. Therefore, pursuant to 37 C.F.R. § 1.107(b), Applicant respectfully requests an affidavit from the Examiner attesting to the fact that the disclosure of polygons in *Behensky et al.* teaches one of ordinary skill in the art that the use of these polygons to represent data in other systems results in the reduction of data base storage, as *Behensky et al.*, in addition to not teaching the use of polygons for real terrain data, does not teach that the use of polygons would result in a reduction of data base storage. Applicant submits that any such teaching comes only from the present specification.

In conclusion, Applicant has made numerous amendments in an earnest attempt to clear up all 35 U.S.C. § 112, second paragraph issues. Should the examiner believe any 35 U.S.C. § 112 issues remain, Applicant would appreciate a call to the undersigned so that any remaining issues my be dealt with by Examiner's amendment, if possible. Additionally, Applicant has amended the claims to recite that the terrain data represents real terrestrial terrain, and to recite that it is generated from elevation data of the real terrestrial terrain. For the reasons described above, Applicant submits the present invention, as currently claimed, is unobvious over the references of record.

For the foregoing reasons, Applicant submits that all objections and rejections have been overcome. Applicant submits that all pending claims are in condition for allowance and allowance of the same is respectfully requested.

Respectfully submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: July 10, 1995

Keith G. Askoff
Reg. No. 33,828
12400 Wilshire Boulevard
Seventh Floor
Los Angeles, California 90025
(408) 720-8598

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on July 10, 1995
Date of Deposit

Carolyn C. Caires
Name of Person Mailing Correspondence

Carolyn C. Caires
Signature

7/10/95
Date

01342

Attorney's Docket No.: 02055.P002 Patent

In the Application of: Jed Margolin (inventor(s))

Serial No.: 08/274,394

Filed: July 11, 1994

For: PILOT AID USING SYNTHETIC REALITY (title)

THE COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SIR: Transmitted herewith is an Amendment for the above application.

____ Small entity status of this application under 37 C.F.R. §§ 1.9 and 1.27 has been established by a verified statement previously submitted.

____ A verified statement to establish small entity status under 37 C.F.R. §§ 1.9 and 1.27 is enclosed.

X No additional fee is required.

The fee has been calculated as shown below:

	(Col. 1) Claims Remaining After Amd.		(Col. 2) Highest No. Previously Paid For	(Col. 3) Present Extra	SMALL ENTITY Rate	SMALL ENTITY Additional Fee	OTHER THAN A SMALL ENTITY Rate	OTHER THAN A SMALL ENTITY Additional Fee
Total Claims	* 37	Minus	** 39	-0-	x11	$ -0-	x22	$
Indep. Claims	* 4	Minus	*** 5	-0-	x38	$ -0-	x76	$
First Presentation of Multiple Dependent Claim(s)					+120	$ -0-	+240	$
					Total Add. Fee	$ -0-	Total Add. Fee	$

* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.

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____ A check in the amount of $____ is attached for presentation of additional claim(s).

____ Applicant(s) hereby Petition(s) for an Extension of Time of ____ month(s) pursuant to 37 C.F.R. § 1.136(a).

____ A check for $____ is attached for processing fees under 37 C.F.R. § 1.17.

____ Please charge my Deposit Account No. 02-2666 the amount of $____. **A duplicate copy of this sheet is enclosed.**

X The Commissioner is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No. 02-2666 **(a duplicate copy of this sheet is enclosed)**:

X Any additional filing fees required under 37 C.F.R. § 1.16 for presentation of extra claims.

X Any extension or petition fees under 37 C.F.R. § 1.17.

BLAKELY SOKOLOFF TAYLOR & ZAFMAN

Date: July 10, 1995

[signature]
Keith G. Askoff

Reg. No. 33,828

12400 Wilshire Boulevard
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Los Angeles, California 90025
(408) 720-8598

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on July 10, 1995
Date of Deposit

Carolyn C. Caires
Name of Person Mailing Correspondence

Carolyn C. Caires — 7/10/95
Signature — Date

(LJV/wes/cak 10/01

02055.P002C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of:

Jed Margolin

Serial No.: 08/513,298

Filed: August 9, 1995

For: PILOT AID USING SYNTHETIC REALITY

Examiner: Not assigned yet

Art Unit: 2304

RECEIVED
NOV 07 1995
GROUP 2300

Hon. Commissioner of Patents
and Trademarks
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

IN THE DOCKET NUMBER

Please change the attorney docket number to:

--02055.P002C--

(i. e. add a "C" at the end.)

IN THE CLAIMS

Please enter the amendment mailed on July 10, 1995, submitted under 37 C. F. R. § 1.116, but unentered in the parent application.

REMARKS

Please consider the remarks in the above referenced amendment, submitted but unentered in the parent application.

Respectfully submitted,

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: October 18, 1995

Keith G. Askoff
Reg. No. 33,828

12400 Wilshire Boulevard
Seventh Floor
Los Angeles, California 90025-1026
(408) 720-8598

FIRST CLASS CERTIFICATE OF MAILING
(37 C.F.R. § 1.8(a))

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on October 18, 1995.
Date of Deposit

Edith Fuentes
Name of Person Mailing Correspondence

Signature

10-18-95
Date

OCT 20 1995 MAIL ROOM PAT. & TRADEMARK O.

Attorney's Docket No.: 02055.P002C

Patent

In re the Application of: Jed Margolin

(inventor(s))

Application No.: 08/513,298

Filed: August 9, 1995

For: PILOT AID USING SYNTHETIC REALITY

(title)

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THE COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SIR: Transmitted herewith is an Amendment for the above application.

______ Small entity status of this application under 37 C.F.R. §§ 1.9 and 1.27 has been established by a verified statement previously submitted.

______ A verified statement to establish small entity status under 37 C.F.R. §§ 1.9 and 1.27 is enclosed.

_X_ No additional fee is required.

______ ____________________

The fee has been calculated as shown below:

	(Col. 1) Claims Remaining After Amd.		(Col. 2) Highest No. Previously Paid For	(Col. 3) Present Extra
Total Claims	* 37	Minus	** 37	0
Indep. Claims	* 4	Minus	*** 4	0
[ ] First Presentation of Multiple Dependent Claim(s)				

SMALL ENTITY Rate	Additional Fee	OTHER THAN A SMALL ENTITY Rate	Additional Fee
x11	$ 0	x22	$
x39	$ 0	x78	$
+125	$ 0	+250	$
Total Add. Fee	$ 0	Total Add. Fee	$

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** If the "Highest No. Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.

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______ A check in the amount of $________ is attached for presentation of additional claim(s).

______ Applicant(s) hereby Petition(s) for an Extension of Time of ______ month(s) pursuant to 37 C.F.R. § 1.136(a).

______ A check for $________ is attached for processing fees under 37 C.F.R. § 1.17.

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_X_ The Commissioner is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No. 02-2666 **(a duplicate copy of this sheet is enclosed):**

- _X_ Any additional filing fees required under 37 C.F.R. § 1.16 for presentation of extra claims.
- _X_ Any extension or petition fees under 37 C.F.R. § 1.17.

BLAKELY SOKOLOFF TAYLOR & ZAFMAN

Date: October 18, 1995

[signature]
Keith G. Askoff

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on October 18, 1995
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Edith Fuentes
Name of Person Mailing Correspondence

[signature]
Signature

10-18-95
Date

(LJV/cak 10/02/95)

01346

OCT 20 1995

Attorney's Docket No.: 02055.P002C

Patent

In re the Application of: Jed Margolin

(inventor(s))

Application No.: 08/513,298

Filed: August 9, 1995

For: PILOT AID USING SYNTHETIC REALITY

(title)

RECEIVED NOV 07 1995 GROUP 2300

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Washington, D.C. 20231

SIR: Transmitted herewith is an Amendment for the above application.

____ Small entity status of this application under 37 C.F.R. §§ 1.9 and 1.27 has been established by a verified statement previously submitted.

____ A verified statement to establish small entity status under 37 C.F.R. §§ 1.9 and 1.27 is enclosed.

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	(Col. 1) Claims Remaining After Amd.		(Col. 2) Highest No. Previously Paid For	(Col. 3) Present Extra	SMALL ENTITY Rate	SMALL ENTITY Additional Fee	OTHER THAN A SMALL ENTITY Rate	OTHER THAN A SMALL ENTITY Additional Fee
Total Claims	* 37	Minus	** 37	0	x11	$ 0	x22	$
Indep. Claims	* 4	Minus	*** 4	0	x39	$ 0	x78	$
[ ] First Presentation of Multiple Dependent Claim(s)					+125	$ 0	+250	$
					Total Add. Fee	$ 0	Total Add. Fee	$

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** If the "Highest No. Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.

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____ A check for $_______ is attached for processing fees under 37 C.F.R. § 1.17.

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- X Any additional filing fees required under 37 C.F.R. § 1.16 for presentation of extra claims.
- X Any extension or petition fees under 37 C.F.R. § 1.17.

BLAKELY SOKOLOFF TAYLOR & ZAFMAN

Date: October 18, 1995

Keith G. Askoff

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Edith Fuentes
Name of Person Mailing Correspondence

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10-18-95
Date

(LJV/cak 10/02/95)

01347

Part III DETAILED ACTION

Notice to Applicants

1. This office action is responsive to the preliminary amendment filed on October 20, 1995. As per request, the amendment mailed on July 10, 1995 of the parent application, serial number 08/274,394 which was abandoned on October 16, 1995, has been enter.

2. In the amendment filed on July 10, 1995, claims 1, 5-7, 11-13, 17-22, 31-32, 36-39 have been amended. Claims 29-30 have been canceled. Thus, claims 1-28 and 31-39 are pending.

3. The rejections under 35 U.S.C. § 112, second paragraph, have been withdrawn upon the amended claims.

Claim Rejections - 35 USC § 103

4. The following is a quotation of 35 U.S.C. § 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.
>
> Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this

08/513,298

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED INVENTOR		ATTORNEY DOCKET NO.
08/513,298	08/09/95	MARGOLIN	J	02055.P002

B3M1/0122

EDWIN H TAYLOR
BLAKELY SOKOLOFF TAYLOR & ZAFMAN
12400 WILSHIRE BLVD SEVENTH FLOOR
LOS ANGELES CA 90025

EXAMINER: ~~NGUYEN, T~~

ART UNIT	PAPER NUMBER
2304	15

DATE MAILED: 01/22/96

This is a communication from the examiner in charge of your application.
COMMISSIONER OF PATENTS AND TRADEMARKS

☐ This application has been examined ☒ Responsive to communication filed on 10/20/95 ☐ This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), 0 days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. ☒ Notice of References Cited by Examiner, PTO-892.
2. ☐ Notice of Draftsman's Patent Drawing Review, PTO-948.
3. ☐ Notice of Art Cited by Applicant, PTO-1449.
4. ☐ Notice of Informal Patent Application, PTO-152.
5. ☐ Information on How to Effect Drawing Changes, PTO-1474.
6. ☐ ______

Part II SUMMARY OF ACTION

1. ☒ Claims 1-28, 31-39 are pending in the application.

   Of the above, claims ______ are withdrawn from consideration.

2. ☒ Claims 29-30 have been cancelled.
3. ☐ Claims ______ are allowed.
4. ☒ Claims 1-28, 31-39 are rejected.
5. ☐ Claims ______ are objected to.
6. ☐ Claims ______ are subject to restriction or election requirement.
7. ☐ This application has been filed with informal drawings under 37 C.F.R. 1.85 which are acceptable for examination purposes.
8. ☐ Formal drawings are required in response to this Office action.
9. ☐ The corrected or substitute drawings have been received on ______. Under 37 C.F.R. 1.84 these drawings are ☐ acceptable; ☐ not acceptable (see explanation or Notice of Draftsman's Patent Drawing Review, PTO-948).
10. ☐ The proposed additional or substitute sheet(s) of drawings, filed on ______, has (have) been ☐ approved by the examiner; ☐ disapproved by the examiner (see explanation).
11. ☐ The proposed drawing correction, filed ______, has been ☐ approved; ☐ disapproved (see explanation).
12. ☐ Acknowledgement is made of the claim for priority under 35 U.S.C. 119. The certified copy has ☐ been received ☐ not been received ☐ been filed in parent application, serial no. ______ ; filed on ______.
13. ☐ Since this application apppears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. ☐ Other

EXAMINER'S ACTION

01349

PTOL-326 (Rev. 2/93)

Part III DETAILED ACTION

Notice to Applicants

1. This office action is responsive to the amendment filed on February 13, 1995 . As per request, claims 1-13 have been amended. Claims 14-39 have been added. Thus, claims 1-39 are pending.

2. New title has been entered.

Election/Restriction

3. Newly submitted claims 29-30 are directed to an invention that is independent or distinct from the invention originally claimed for the following reason:

Newly added claims 29 and 30 are directed to a method for producing a terrain data based comprising terrain data and said terrain data represented as one or more polygons. However, the original set of claims are directed to a pilot aid which uses an aircraft's position and attitude to transform data from a digital based to present a pilot with a synthesized three dimensional projected view of the world.

Since applicant has received an action on the merits for the originally presented invention, this invention has been constructively elected by original presentation for prosecution

Structure of Digital Data

The Earth Science Information Centers (ESIC) distribute digital cartographic/geographic data files produced by the U.S. Geological Survey (USGS) as part of the National Mapping Program. The data files are grouped into four basic types. The first type, called a Digital Line Graph (DLG), is line map information in digital form. These data files include information on planimetric base categories, such as transportation, hydrography, and boundaries. The second type, called a Digital Elevation Model (DEM), consists of a sampled array of elevations for ground positions that are usually at regularly spaced intervals. The third type, Land Use and Land Cover digital data, provide information on nine major classes of land use such as urban, agricultural, or forest as well as associated map data such as political units and Federal land ownership. The fourth type, the Geographic Names Information System, provides primary information for known places, features, and areas in the United States identified by a proper name.

The digital cartographic data files from selected quadrangles currently available from ESIC include the following:

- Digital Elevation Models (DEM's)
  - 7.5-minute
  - 15-minute
  - 30-minute
  - 1-degree

- Digital Line Graphs (DLG's)
  - 1:24,000-scale
  - 1:62,500-scale
  - 1:63,360-scale
  - 1:100,000-scale
  - 1:2,000,000-scale

- Land Use and Land Cover digital data
  - 1:250,000- and 1:100,000-scale Land Use and Land Cover and associated maps
  - 1:250,000-scale Alaska Interim Land Cover

- Geographic Names Information System

The digital data are useful for the production of cartographic products such as plotting base maps and for various kinds of spatial analysis. A major use of these digital cartographic/geographic data is to combine them with other geographically referenced data, enabling scientists to conduct automated analyses in support of various decision making processes.

The information for the following pages on "Structure of Digital Data" was obtained from sections of the DATA USERS GUIDES listed:

DATA USERS GUIDES

1: Digital Line Graphs from 1:24,000-Scale Maps - $2
2: Digital Line Graphs from 1:100,000-Scale Maps - $1.50
3: Digital Line Graphs from 1:2,000,000-Scale Maps - $1.50
4: Land Use and Land Cover from 1:2,000,000-Scale Maps - $1
5: Digital Elevation Models - $1
6: Geographic Names Information System - $1
7: Alaska Interim Land Cover Mapping Program - $1

Data Users Guides 1-7 replace Geological Survey Circular 895 B-G.

ALASKA DIGITAL ELEVATION MODELS

- The product consists of a regular array of elevations referenced horizontally to the geographic (latitude/longitude) coordinate system of NAD 27 or NAD 83.
- Elevation data on the quadrangle neatlines (all four sides) share edge profiles with the surrounding eight quadrangles.
- Elevations are in meters or feet relative to NGVD 29.
- The data are ordered from south to north in profiles that are ordered from west to east.

Characteristics

7.5-MINUTE Alaska DEM's have the following characteristics:

- The unit of coverage corresponds to four basic quadrangle sizes for 1:24,000- and 1:25,000-scale graphics (depending on latitude):

Cell size limits

7.5 x 18 minutes	State of Alaska north of 68° N latitude
7.5 x 15 minutes	Between 62° N and 68° N latitude
7.5 x 11.25 minutes	Between 59° N and 62° N latitude
7.5 x 10 minutes	State of Alaska south of 59° N latitude

- The longitudinal limits of these cells are computed east and west of the -150 degree meridian. The north-south cell limits conform to even multiples of 7.5 minutes of latitude.
- The data are collected with a 1- x 2-arc-second spacing in latitude and longitude, respectively. The first and last data points along a profile are at the integer degrees of latitude. A profile will therefore contain 451 elevations.

Characteristics

15-MINUTE Alaska DEM's have the following characteristics:

- The unit of coverage corresponds to four basic quadrangle sizes for 1:63,360-scale graphics (depending on latitude):

Cell size limits

15 x 36 minutes	State of Alaska north of 68° N latitude
15 x 30 minutes	Between 62° N and 68° N latitude
15 x 22.5 minutes	Between 59° N and 62° N latitude
15 x 20 minutes	State of Alaska south of 59° N latitude

- The longitudinal limits of these cells are computed east and west of the -150 degree meridian. The north-south cell limits conform to even multiples of 15 minutes of latitude.
- The data are collected with a 2- x 3-arc-second spacing in latitude, and longitude, respectively. The first and last data points along a profile are at the integer degrees of latitude. A profile will therefore contain 451 elevations.

)EGREE DIGITAL ELEVATION MC LS

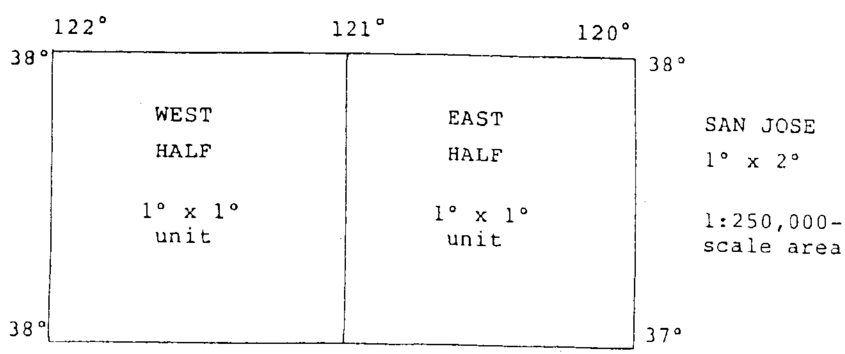
1-Degree DEM (3- x 3-arc-second data spacing). Provides coverage in 1- x 1-degree blocks. Two products (three in some regions of Alaska) provide the same coverage as a standard USGS 1- x 2-degree map series quadrangle. The basic elevation model is produced by or for the Defense Mapping Agency (DMA), but is distributed by USGS in the DEM data record format.

Characteristics

A 1-degree DEM has the following characteristics:

- The product consists of a regular array of elevations referenced horizontally on the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 Datum (WGS 72) or the World Geodetic System of 1984 (WGS 84).
- The unit of coverage is a 1- x 1-degree block. Elevation data on the integer degree lines (all four sides) correspond with the same profiles on the surrounding eight blocks.
- Elevations are in meters relative to NGVD 29 in the continental U.S. and local mean sea level in Hawaii and Puerto Rico.
- The data are ordered from south to north in profiles that are ordered from west to east.
- Spacing of the elevations along each profile is 3 arc-seconds. The first and last data points are at the integer degrees of latitude. A profile will therefore contain 1,201 elevations.
- Spacing between profiles varies by latitude; however, the first and last data points are at the integer degrees of longitude. North of 50° degrees N and south of 70° N, the spacing is 6 arc-seconds with 601 profiles per product. For the remainder of Alaska north of 70° N the spacing is 9 arc-seconds with 401 profiles per product.

For U.S. 1:250,000-scale 1 degree by 2 degree areas, you need to order TWO 1 degree by 1 degree DEM units: EAST HALF and WEST HALF. They are TWO separate DEM units with TWO separate costs: $7 for each half for a total of $14 for the entire area, if you are ordering six or more units.



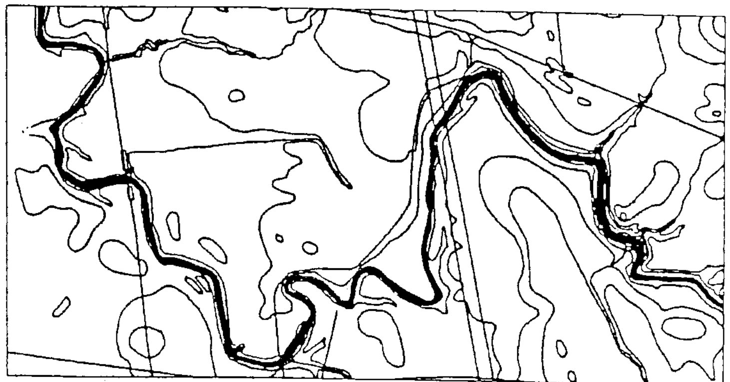
For ALASKA 1:250,000-scale DEMs, some areas require THREE units: EAST HALF, CENTRAL HALF and WEST HALF, if you want the entire area.

01353

U.S. Department of the Interior
U.S. Geological Survey
Earth Science
Information Center (ESIC)

Factsheet

US GeoData
Digital Line Graphs


Plot of DLG data—northwest corner of Bombay, New York-Quebec Quadrangle, 1:24,000-scale showing hydrography, roads and trails, railroads, miscellaneous transportation, and hypsography.

Digital line graph data

Digital line graph (DLG) data are digital representations of cartographic information. DLG's of map features are converted to digital form from maps and related sources. U.S. Geological Survey (USGS) DLG data are classified as large, intermediate, and small scale.

Data sources

Large-scale DLG data are derived from USGS 1:20,000-, 1:24,000-, and 1:25,000-scale 7.5-minute topographic quadrangle maps. If 7.5-minute maps are not available, sources are used in the following order of preference: (1) advance manuscripts for 7.5-minute maps; (2) published 15-minute quadrangles at 1:62,500 scale (1:63,360 scale for Alaska); and (3) archival compilation materials for 15-minute quadrangles such as 1:48,000-scale compilations.

Intermediate-scale DLG data are derived from USGS 1:100,000-scale 30- by 60-minute quadrangle maps. If these maps are not available, Bureau of Land Management planimetric maps at a scale of 1:100,000 are used, followed by archival compilation materials.

Small-scale DLG data are derived from such maps as the USGS 1:2,000,000-scale sectional maps of the National Atlas of the United States of America. Alaska hydrography data were collected at 1:1,000,000 scale from Landsat images from 1979. Other categories of data were revised from 1979-80 sources.

Unit size and file extent

Large-scale DLG data are produced in 7.5-minute units that correspond to USGS 1:20,000-, 1:24,000-, and 1:25,000-scale topographic quadrangle maps. However, some older units in the western United States cover 15-minute areas and correspond to maps at 1:62,500 scale. The unit sizes in Alaska vary depending on latitude. Units south of 59° N. cover 15- by 20-minute areas; between 59° and 62° N., 15- by 22.5-minute areas; between 62° and 68° N., 15- by 30-minute areas; and north of 68° N., 15- by 36-minute areas (all values are latitude and longitude, respectively).

Intermediate-scale DLG data are sold in 30-minute units that correspond to the east or west half of USGS 30- by 60-minute 1:100,000-scale topographic quadrangle maps. Each 30-minute unit is produced and distributed as four 15- by 15-minute cells, except in high-density areas, where the 15-minute cells may be divided into four 7.5-minute cells.

Intermediate-scale hydrography and transportation DLG data are sold on compact disc-read only memory (CD-ROM). Each disc contains all the 15- by 15-minute cells within the 1:100,000-scale quadrangles that cover a State or States. Currently 3 areas within 14 planned sectional regions in the United States are available: Area 3—southeastern States of NC, SC, and GA; Area 4—FL; and Area 13—northwestern States of WA, OR, and ID.

Small-scale DLG data that correspond to USGS 1:2,000,000-scale sectional maps of the National Atlas are sold in 21 units. Fifteen sections cover the continental United States, five cover Alaska, and one covers Hawaii. These sectional DLG's are usually sold in multi-State units. Some, however, may cover only one State or a portion of a State. All 21 units are available on a single CD-ROM.

All nonstandard quadrangles with neatlines that extend beyond the standard unit size to accommodate overedge boundaries are collected as multiples of the standard unit size. Data covering a 7.5- by 8.5-minute quadrangle area would, therefore, be sold as two 7.5-minute units.

Data content

Large-scale DLG data are available in nine categories: (1) hypsography, including contours and supplementary spot elevations; (2) hydrography, including flowing water, standing water, and wetlands; (3) vegetative surface cover, including woods, scrub, orchards, vineyards, and vegetative features associated with wetlands; (4) nonvegetative features, including lava, sand, and gravel; (5) boundaries, including State, county, city, and other national and State lands such as forests and parks; (6) survey control and markers, including horizontal and vertical positions (third order or better); (7) transportation, including roads and trails, railroads, pipelines, and transmission lines; (8) manmade features, including cultural features not collected in other major data categories such as buildings; and (9) the Public Land Survey System, including township, range, and section line information.

Presently, intermediate-scale DLG's are sold in five categories: (1) Public Land Survey System; (2) boundaries; (3) transportation; (4) hydrography; and (5) hypsography.

Small-scale DLG data are sold in three categories: (1) boundaries, including political and administrative boundaries; (2) transportation, including roads and trails, railroads, and cultural features (airports and the Alaska pipeline); and (3) hydrography, including streams and water bodies, and hypsography (Continental Divide only). All of these categories are also included in the 1:2,000,000-scale CD-ROM.

Data structure

All DLG data distributed by the USGS are DLG - Level 3 (DLG-3), which means the data contain a full range of attribute codes, have full topological structuring, and have passed certain quality-control checks. The DLG-3 concept is based on graph theory in which a two-dimensional diagram is expressed as a direct graph composed of a set of nodes, lines, and areas that express logical relationships with minimal redundancy. Nodes define the end points of lines. A line is an ordered set of points that describe the position and shape of a linear feature of the map. An area is a continuous, unbroken region of the map bounded by lines. Applied to a map, this concept expresses spatial relationships between map elements that are obvious when the map is examined. The spatial relationships between features on a map include concepts such as location, adjacency, and connections. Data that maintain the spatial relationships inherent in the map are topologically structured.

Attribute codes

Attribute codes are used to describe the physical and cultural characteristics of DLG node, line, and area elements. Attribute codes are used to reduce redundant information, provide enough reference information to support integration with larger data base, and describe the relationships between cartographic elements. Each DLG element has one or more attribute codes composed of a three-digit major code and a four-digit minor code. For example, with the 1:2,000,000-scale DLG data, the line attribute code 290 5001 has a major code (290), meaning road, with a minor code (5001) identifying the road as an interstate.

Data formats

Large- and intermediate-scale DLG's are available in standard and optional formats. The standard format has reduced storage requirements, 144-byte logical record length, an internal file coordinate system (thousandths of a map inch), and topological linkages contained only in the line elements. The optional format is easy to use with an 80-byte logical record length, a ground planimetric coordinate system (Universal Transverse Mercator), and topological linkages contained in node, line, and area elements.

Small-scale DLG's are available in standard, optional, and graphic formats. The standard format is the same as the large- and intermediate-scale DLG's. The optional format is also the same as the large and intermediate scales, except that it uses the ground planimetric coordinate system of the Albers Equal-Area Conic projection. The graphic format is compatible with Geological Survey Cartographic Automatic Mapping (GS-CAM) plotting software, with a 20-byte logical record length; a geographic (latitude-longitude) coordinate system expressed in degrees, minutes, and seconds; and no topological linkages. All three formats are available on the 1:2,000,000-scale CD-ROM.

Data records

The standard format data are organized into 9 record types and the optional format data into 11 record types. For descriptions of these record types, refer to Data Users Guide 1—Digital Line Graphs from 1:24,000-Scale Maps, Data Users Guide 2—Digital Line Graphs from 1:100,000-Scale Maps, and Data Users Guide 3—Digital Line Graphs from 1:2,000,000-Scale Maps.

The graphic format data are DLG line records organized by feature type and formatted into two record types: one line identifier record and multiple latitude-longitude records.

Data accuracy validation

DLG data do not carry quantified accuracy statements. However, the data files are checked and validated before they are released for distribution for file fidelity and completeness, attribute accuracy, and topological fidelity. For large- and intermediate-scale DLG's, additional data validation such as edge matching and quality control flagging is performed.

US GeoData Sampler

The US GeoData Sampler is available for a nominal charge. Data contents include the 7.5-minute digital elevation model (DEM) and the 1:24,000-scale DLG for Tumwater, Washington; the 1:100,000-scale DLG for Tacoma, Washington; the 1:2,000,000-scale DLG for the northwestern States (WA, OR, and ID); the 1- by 2-degree land use and land cover data for Seattle, Washington; the 1- by 1-degree DEM for Seattle, Washington East; and the Geographic Names Information System data for the State of Washington.

Ordering instructions

DLG data are written as ANSI-standard ASCII characters in fixed-block format on unlabeled or ANSI labeled nine-track magnetic tape at a 1,600-bpi or 6,250-bpi density. DLG's may be ordered by specifying the scale, format, maximum block size, tape density, tape label, and either the topographic quadrangle name or section, or the southeast latitude and longitude corner coordinates of the sales unit.

The US GeoData Sampler can be ordered by name and is offered in standard or optional ASCII DLG formats, on either one 6,250-bpi or three 1,600-bpi tapes.

To assist you in ordering, the Earth Science Information Center (ESIC) can furnish indexes, price lists, and order forms. Data Users Guides are included with each order.

For further information, contact the USGS, Earth Science Information Center, 507 National Center, Reston, VA 22092, or call 1-800-USA-MAPS.

DIGITAL LINE GRAPHS FROM 1:24,000-SCALE MAPS

This document describes the Digital Line Graphs (DLG's) prepared primarily from the 1:24,000 materials associated with the USGS Topographic Map Series. The series will eventually provide complete national coverage.

DATA CONTENT

The DLG data files derived from the 1:24,000-scale and other large-scale maps contain selected base categories of cartographic data in digital form; these data categories do not necessarily correspond to the traditional feature separates associated with the maps. The attribute coding scheme for these data has undergone several revisions since the start of the digital program. A major revision of these codes has been printed as Standards for Digital Line Graphs - Part 3, Attribute Coding, which is available for purchase from a USGS ESIC office (see the ordering information inside the front cover). Currently, DLG data entered in the National Digital Cartographic Data Base (NDCDB) are coded in accordance with the Standards for Digital Line Graphs. The implementation of the new coding standards will require the updating of existing files in the NDCDB in order to have a consistent product available for users. Software and procedures are being developed to convert existing data files to these codes during the next several years. Priority will be given to converting files retrieved in response to sales requests. In the meantime, a data base query will provide identification of the coding scheme used for any file in the NDCDB. This information will be supplied to customers when orders are submitted, and upon transmittal of data files. The following categories are included in current large-scale DLG files:

- Boundaries -- This category of data consists of (1) political boundaries that identify States, counties, cities, and other municipalities, and (2) administrative boundaries that identify areas such as National and State forests. Political and administrative boundaries are always collected as a single data set.

- Hydrography -- This category of data is currently being collected as combined hydrography consisting of all flowing water, standing water, and wetlands.

  Prior to 1983, hydrographic data were differentiated into two components: streams and water bodies. Streams represent flowing water and were digitized as a network intended for hydrologic flow modeling. Streams included the banks of double-line rivers and centerline connectors placed through double-line rivers and lakes. Water bodies include standing water such as lakes and ponds. Wetlands and coastal hydrographic data were not collected.

- Public Land Survey System (PLSS) -- This category of data describes the rectangular system of land surveys that is administered by the U.S. Bureau of Land Management. PLSS data are only collected for areas falling solely, or in part, within the States that were formed from the public domain. The PLSS subdivides the public domain and represents property boundaries or references to property boundaries. These DLG data are not intended to be official or authoritative. They are presented as cartographic reference information. The only legal basis for determining land boundaries remains the original survey.

continued

- Transportation -- This category of data includes major transportation systems collected in three separate overlays labeled: (1) Roads and Trails, (2) Railroads, and (3) Pipelines, Transmission Lines, and Miscellaneous Transportation Features.

  In the last quarter of 1985, new transportation attribute codes were implemented. The principal difference between the old and new coding schemes is that under the old transportation subcategory, certain miscellaneous transportation features were not collected and descriptive attribute codes were not used.

- Other Significant Manmade Structures -- This category of data includes miscellaneous cultural features not included in the other major data categories.

  New attribute codes for Other Significant Manmade Structures were implemented in the last quarter of 1985. Very little data from this category currently reside in the NDCDB.

The attribute codes for the following base categories were newly defined in late 1985. Currently, there are very little data available in these categories.

- Hypsography -- This category of data consists of information on topographic relief (primarily contour data).

- Surface Cover -- This category of data consists of information about vegetative surface cover such as woods, scrub, orchards, and vineyards. Vegetative features associated with wetlands, such as marshes and swamps, are collected under Hydrography.

- Non-Vegetative Surface Features -- This category of data consists of information about the natural surface of the Earth as symbolized on the map such as lava, sand, and gravel features. This category is not all-inclusive, as other non-vegetative surface features are found in the category of Hydrography.

- Survey Control and Markers -- This category of data consists of information about the points of established position and third-order or better elevations that are used as fixed references in positioning and correlating map features.

DIGITAL LINE GRAPHS FROM 1:2,000,000-SCALE MAPS

DATA CONTENT

The DLG data files derived from the 1:2,000,000-scale maps contain selected base categories of cartographic data in digital form. The data files are derived from the sectional maps of the 1970 National Atlas of the United States of America. The following categories are included in current 1:2,000,000-scale DLG files:

- Boundaries -- This category of data includes boundary information collected in two separate subcategories: (1) Political Boundaries and (2) Administrative Boundaries.
- Hydrography -- This category of data includes features collected in three separate subcategories: (1) Streams, (2) Water Bodies, and (3) Hypsography (Continental Divide only).
- Transportation -- This category of data includes major transportation systems collected in three separate subcategories: (1) Roads and Trails, (2) Railroads, and (3) Cultural Features (airports and Alaska pipeline).

DISTRIBUTION FORMATS

The 1:2,000,000-scale DLG data are available in three distribution formats: (1) standard, (2) optional, and (3) graphic.

The **Standard** distribution format was designed to minimize storage requirements. Explicit topological linkages are contained only in the line elements.

The **Optional** distribution format was designed for data interchange. These files are typically larger than those in the standard format but, for certain applications, can simplify processing requirements. Topological linkages are explicitly encoded between all line and node elements, and all line and area elements. This structure allows a polygon data structure to be easily created.

The **Graphic** distribution format was designed to be compatible with the GS-CAM (Geological Survey - Cartographic Automatic Mapping) software. This software provides for plotting line and point information using a variety of map projections, scales, and graphic symbologies.

The files in the graphic distribution format are derived from the topologically structured DLG data described above, and contain a subset of the line and attribute code information in the DLG files. No node or area information is stored in these files. These files are not topologically structured.

The small-scale (1:2,000,000-scale) DLG sectional U.S. coverage data is available on a CD-ROM for $32.

DATA CONTENT

The DLG data files derived from the 1:100,000-scale maps contain selected base categories of cartographic data in digital form; these data categories do not necessarily correspond to the traditional feature separates associated with the maps. The following categories are included in current 1:100,000 DLG files:

- Hydrography -- This category of data describes combined hydrography consisting of all flowing water, standing water, and wetlands.

- Transportation -- This category of data includes major transportation systems collected in three separate subcategories labeled: (1) roads and trails, (2) railroads, and (3) pipelines, transmission lines, and miscellaneous transportation.

- Hypsography -- This category of data consists of information on topographic relief (primarily contour data), and supplementary spot elevations.

- Boundaries -- This category of data consists of (1) political boundaries that identify States, counties, cities, and other municipalities, and (2) administrative boundaries that identify areas such as National and State forests. Political and administrative boundaries are always collected as a single data set.

- Public Land Survey System (PLSS) -- This category of data describes the rectangular system of land surveys that is administered by the U.S. Bureau of Land Management. PLSS data are only collected for areas falling solely, or in part, within the States that were formed from the public domain. The PLSS subdivides the public domain and represents property boundaries or references to property boundaries. These DLG data are not intended to be official or authoritative. They are presented as cartographic reference information. The only legal basis for determining land boundaries remains the original survey.

The hypsography, boundary, and PLSS categories were authorized for production in late 1987. Currently there is very little data available in these categories.

The remaining categories: manmade features, survey control, vegetative surface cover, and nonvegetative features are projected to enter the production phase in 1990.

DIGITAL LINE GRAPHS

DISTRIBUTION FORMATS

The 1:24,000-scale and other large-scale DLG data are available in two distribution formats: (1) standard and (2) optional.

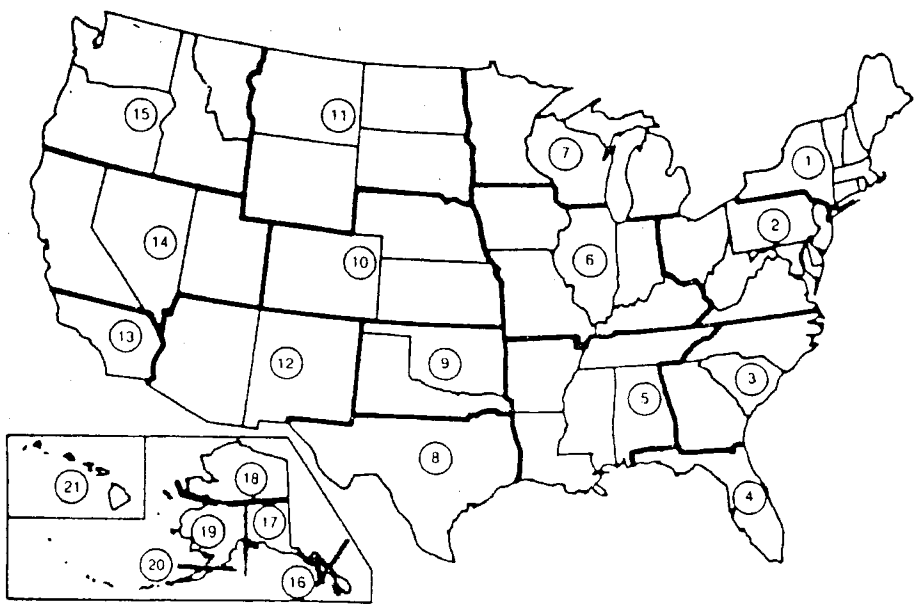
The **Standard** distribution format is intended to minimize storage requirements. Explicit topological linkages are contained only in the line elements (starting node, ending node, area to the left of direction of travel, area to the right of direction of travel).

The **Optional** distribution format was designed to facilitate data usage. The topological relationships explicitly encoded include starting node, ending node, area to the left of direction of travel and area to the right of direction of travel for line elements, bounding lines for area elements, and bounding lines for node elements. These files are typically larger than those in the standard format but, for certain applications, can simplify processing requirements. For example, topological linkages are explicitly encoded for all line, node, and area elements, allowing a polygon data structure to be easily created. These linkages facilitate GIS applications of DLG data as well as generation of graphic products.

The characteristics of the standard and optional DLG formats are

Standard and optional DLG format

	Standard	Optional
Character set	8-bit ASCII	8-bit ASCII
Logical record length	144 bytes	80 bytes
Physical record length (blocksize)	Variable in multiples of 144 bytes.	Variable in multiples of 80 bytes.
Coordinate system	Internal file (thousandths of a map inch).	Ground planimetric (UTM).
Topological linkages	Contained only in line elements.	Contained in node, area, and line elements.



Multistate cells used for Digital Line Graphs from 1:2,000,000-scale maps.

INDEX MAP

1 NORTHEASTERN STATES
2 MIDDLE ATLANTIC STATES
3 SOUTHEASTERN STATES
4 FLORIDA
5 SOUTHERN MISSISSIPPI VALLEY STATES
6 CENTRAL MISSISSIPPI VALLEY STATES
7 NORTHERN GREAT LAKES STATES
8 SOUTHERN TEXAS
9 SOUTHERN PLAINS STATES
10 CENTRAL PLAINS STATES
11 NORTHERN PLAINS STATES
12 ARIZONA AND NEW MEXICO
13 SOUTHERN CALIFORNIA
14 CENTRAL PACIFIC STATES
15 NORTHWESTERN STATES
16 SOUTHEASTERN ALASKA
17 CENTRAL ALASKA
18 NORTHERN ALASKA
19 SOUTHWESTERN ALASKA
20 ALEUTIAN ISLANDS
21 HAWAIIAN ISLANDS

APPENDIX --Sample DLG Data File (Standard Distribution Format)
(Each 144-character record is shown as two consecutive 72-character lines.)

```
GLEN ELLEN                                                1968    24000

     3      1     10  -0.122033045000000D 09    0.380180450000000D 08    0.0
                       0.0                      0.0
   0.0                      0.0                      0.0
   0.0                      0.0                      0.0
   0.0                      0.0                      0.0
   0.0                      2  0.610000000000000D 00    0    4
  -0.122625000000000D 03    0.382500000000000D 02  -0.122625000000000D 03
   0.383750000000000D 02  -0.122500000000000D 03    0.383750000000000D 02
  -0.122500000000000D 03    0.382500000000000D 02

   0.609594407590000D 00  -0.288178569420000D-02    0.538248793410000D 06
   0.424037445560000D 07      4
SW -8971-11376NW -8955 11375NE  8955 11376SE  8971-11376

     1

BOUNDARIES (24&25)     795    16   795     7   530    20

N       1 -8971-11376      0     0

N       2 -8955 11375      0     0

N       3  8955 11376      0     0

N       4  8971-11376      0     0

N       5 -8966  3203      0     0

N       6  2101 11374      0     0

N       7  5832 11376      0     0

N       8  7513 11376      0     0

N       9  8956  7494      0     0

N      10  8961  2884      0     0

N      11  3469 10371      0     0

N      12  5530  9112      0     0

N      13 -3115-10127      0     0

N      14  7520 11175      1     0
    90      1
```

nicates with the satellites via an S-band uplink and downlink.

Civilian GPS receivers decode one of the satellites' two biphase spread-spectrum codes to determine position. The code called the Coarse/Acquisition code (C/A code), is a pseudorandom-noise (PRN) modulation at 1.023 MHz on the L1 carrier frequency. The other PRN code, called the Precise code (P code), modulates both the L1 and L2 carrier frequencies at 10.23 MHz to provide better position accuracy. The P Code is intended for military

the receivers generally use crystal clocks having long-term frequency stabilities of 10^{7}/day. The receiver-clock error dominates, so

$$\text{Pseudorange} = \rho + c\Delta t_R, \text{ and}$$

$$\rho = \text{pseudorange} - c\Delta t_R$$

The fundamental frequency of the satellite clock is 10.23 MHz. Actually, the satellite-clock error is so small that the GPS must take into account the clock offset caused by relativity effects.

You are here

To locate a point P on the earth's surface relative to a satellite located at point S_1 **(Fig A)**, a receiver must calculate the following vector relationships:

$$|\overrightarrow{\rho - c\Delta t_R}| = |\vec{S}| - |\vec{P}|$$

$$(\rho - c\Delta t_R)^2 = (X_1 - X_0)^2 + (Y_1 - Y_0)^2 + (Z_1 - Z_0)^2.$$

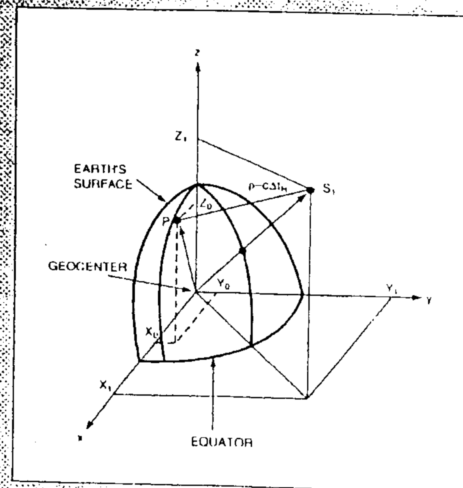


Fig A—A GPS receiver locates a position, P, on the earth's surface by measuring the time of arrival of a pseudorandom-noise code on a satellite signal. The satellite is in orbit at point S. The system makes simultaneous measurements from four satellites (only one shown here) to determine X_0, Y_0, Z_0, and the receiver's clock error (t_R).

The satellite's navigation message contains accurate ephemeris data, which determine X_1, Y_1, and Z_1—the satellite's coordinates from the earth's geocenter. The message also contains correction factors for the satellite's clock error.

The pseudorange equation for one satellite has four unknowns—P's coordinates X_0, Y_0, Z_0 and the receiver's clock error t_R. The receiver's clock error is the same for all the satellites. Thus, the receiver can simultaneously obtain pseudorange data from four different satellites to generate four equations with four unknowns. The receiver's software iteratively solves these equations to determine P's coordinates. The software then translates the geocentric coordinate data to longitude, latitude, and altitude.

With the Selective Availability (SA) feature turned off, GPS receivers typically achieve 15m SEP (spherical error probability) accuracy when tracking the C/A code. When SA is on, the accuracy degrades to 40m SEP. (SA is the DoD's attempt to doctor the GPS signals so that civilian users cannot achieve military accuracy. See **box**, "Glossary," for complete definitions of GPS terms.)

GPS receivers achieve greater accuracy by comparing the satellite information from multiple receivers over long baselines. The technique, called differential GPS, achieves position accuracy of less than 5m SEP on the C/A code and can effectively cancel the effects of SA. By using differencing techniques, differential GPS can track the carrier phase of the L1 frequency and achieve position accuracy to a fraction of the carrier wavelength. This wavelength is approximately 19 cm.

The references give much more detail on the GPS than space allows here. They are arranged in order of complexity ranging from the layman's tutorial in **Ref 1** to the complex analytical treatment of **Ref 4**. You can obtain all of the books from

Navtech Book & Software Store
2775 S Quincy St, Suite 610
Arlington, VA 22206
(800) 628-0885
(703) 931-0500
FAX (703) 931-0503.

01363

GPS RECEIVERS

use. The DoD plans to encrypt the code in the near future.

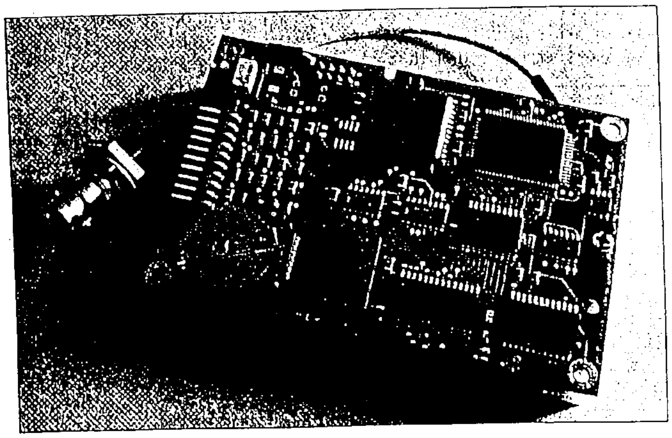
The receivers have omnidirectional antennas for receiving the L1 and L2 signals from several satellites simultaneously. The antennas have low-noise amplifiers and ground planes to reduce multipath signals. The receivers convert the signals to baseband for single or multiple channels. Single-channel receivers are cheaper than multiple-channel receivers, but they must time-multiplex data from multiple satellites. These receivers lose phase-tracking information while breaking and reacquiring lock.

As the price of GPS ICs drops, multiple-channel receivers are becoming more prevalent. Commercially available GPS receivers come in all shapes and sizes. They range from handheld portable products to instrument pods on high-performance aircraft. Novatel's GPSCard is a representative multiple-channel GPS receiver for OEM applications.

Simply plug in a card

The GPSCard is available with an 8-bit ISA bus or Eurocard connector. The card accepts signals from an external GPS antenna and feeds them to 10 parallel tracking channels. High-speed samplers convert each channel's analog data to digital data. Proprietary ASICs digitally process the data to calculate the receiver's position.

The GPSCard specifies a time to the first satellite fix of 2 minutes from a cold start. A cold start means that the receiver's memory has no ephemeris data from any satellite. A GPS satellite broadcasts its ephemeris data in a navigation message that modulates the L1 and L2 carrier signals. The receiver must decode the navigation message to store the ephemeris in memory. The card can reacquire a signal within 5 seconds once the memory contains recent satellite ephemeris data via the navigation message.



The GPS 10 Sensor board implements Garmin's Multitrac technology on a 4 × 2.65 × 0.75-in. OEM card. The receiver can track and use as many as eight satellites for accurate positioning.

The GSPCard software lets you enter waypoints to mark off an unchartered route. The software contains a global map based on WGS-84 (Worldwide Geodetic System 1984) coordinates. These coordinates are a best-fit spheroid approximation of the earth's surface. Using a built-in or user-defined survey datum, you can refine your location on the global map.

All GPS receivers specify a zero-baseline measurement accuracy. The zero-baseline specifications are the receiver's accuracy limits taken when using one antenna and two of the receivers in one location. Manufacturers also provide accuracy data for GPS receivers under an assumed operating condition. This condition assumes a certain geometrical dilution of precision (GDOP) for the arrangement of the satellites. The receiver's software calculates the GDOP using a matrix of data from four satellites.

You obtain a receiver's position accuracy by multiplying the GDOP value by the zero-baseline measurement accuracy. GDOP values usually range from 2 to 6. A high GDOP value occurs when the four satellites are bunched close together, which results in poor position accuracy. The lowest GDOP occurs when one satellite is directly overhead and the other three are equally spaced on the horizon. If more than four satellites are in view, a GPS receiver can calculate the various GDOPs to select the four satellites that have the minimum GDOP value.

Civilian surveying, exploration, and navigation equipment use differential GPS to improve position accuracy. The mobile GPS receivers receive the satellite signals in tandem with signals from a reference receiver at a known fixed position on earth. This technique can result in a measuring accuracy of within a centimeter.

GPS receivers specify accuracy with the Selective Availability (SA) feature turned on or off. SA lets the DoD decrease a receiver's position accuracy. When on, SA degrades the C/A code's frequency and the resolution of ephemeris data for civilian use. The intent is to provide more resolution for a military receiver than for a potential adversary receiver using the

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GPS RECEIVERS

same satellite signals. However, the differential GPS technique can effectively cancel the effects of SA, so the feature doesn't make a lot of sense.

From a civilian point of view, SA is a real nuisance and is causing considerable unrest about the future of the GPS. Because the GPS is currently under autocratic control, the DoD can make changes to it at a moment's notice. Another sticky issue is funding. Depending on whose figures you use, GPS operating costs—which includes the replacement of inoperative satellites—could be in excess of $500 million per year. Each satellite has an expected lifetime of 7.5 years. In light of federal-budget constraints, US taxpayers and the Congress may not be willing to pay these costs.

The Russian Glonass satellite positioning system should be operational by 1995. Glonass will provide the same global coverage as the GPS and offers a viable supplement or alternative. However, receivers for the GPS and Glonass are not interoperable. The GPS employs time-division multiple access, and Glonass uses frequency-division multiple-access methods. Clearly, some political issues have to be addressed before a true global system becomes a reality. EDN

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3. Wells, David, *Guide to GPS positioning*, Canadian GPS Associates, Fredericton, New Brunswick, Canada, 1986.
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Article Interest Quotient
(Circle One)
High 473 Medium 474 Low 475

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Aviator's Guide To GPS
Clarke

The overall system provides:

- Accurate 3D (three-dimensional) determination of position, velocity, and time
- Passive operation
- All-weather operation
- Real-time positioning
- Continuous operation
- Usable in a hostile environment (military uses)

It is important to note that GPS receivers operate passively (no communication with the satellite system), therefore, a limitless number of simultaneous users can exist.

In accordance with the Federal Radionavigation Plan (FRP) jointly prepared by the Department of Defense and Department of Transportation:

> . . . many existing navigation systems are under consideration for replacement by GPS beginning in the mid- to late-1990s. GPS may ultimately supplant less-accurate systems such as LORAN-C, Omega, VOR, DME, TACAN, and Transit, thereby substantially reducing federal maintenance and operating costs associated with these current radionavigation systems.

National security caveat

In the interest of U.S. national security, the highly accurate and dependable GPS has built-in features which can deny accurate service to unauthorized users, prevent spoofing (passing of incorrect data meant to deceive users), and reduce receiver susceptibility to jamming.

These security measures, designed only with the military in mind, can cause considerable difficulties for unauthorized users. Essentially, an unauthorized user is defined as anyone without a specific military need and/or mission.

GPS PROGRAM HISTORY

Since the early 1960s the U.S. Air Force (USAF) and U.S. Navy (USN) have operated or studied assorted satellite navigation systems. The navy sponsored two programs, Transit and Timation.

Transit: First operational in 1964, Transit is currently providing surface navigation service for ships.

Timation: A high-tech research program for a two-dimensional (latitude and longitude) navigation system.

During the same period of time, the air force conducted concept studies assessing a three-dimensional (latitude, longitude, and altitude) navigation system called 621B.

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GPS program management

In 1973 the U.S. Deputy Secretary of Defense directed that the air force be the executive service to consolidate the Timation and 621B programs into a single, all-weather navigation system to be called the NAVSTAR Global Positioning System.

The NAVSTAR GPS Joint Program Office (JPO) was established in July 1973 at U.S. Air Force Systems Command/Space and Missile Systems Organization (SAMSO), Los Angeles AFB, California. The JPO is staffed by personnel from the USAF, USN, U.S. Army (USA), U.S. Marine Corps (USMC), U.S. Coast Guard (USCG), U.S. Defense Mapping Agency (DMA), NATO nations, and Australia.

Development phases of GPS

By December of 1973 the JPO had received approval to start the concept validation phase (Phase One) of the GPS program. This phase included concept studies, projected system performance, and feasibility. Phase One was completed in 1979.

Phase Two was subsequently started and included full-scale equipment development (including the development of GPS user equipment) and system testing. That phase ended in 1985.

The third phase (Phase Three) started in 1985, with the production of GPS equipment and further system developments leading to the completed satellite constellation, Master Control Station (MCS), and advanced user equipment.

Operational capability

The term FOC (full operational capability) defines the condition when full and supportable military capability is provided by a system. GPS FOC will be declared by the Secretary of Defense when 24 operational satellites (Block II/IIA types) are in their assigned orbits and when the constellation has successfully completed testing. Three of the 24 satellites will be orbiting spares that can easily be moved to replace a faulty satellite.

An Initial Operational Capability (IOC) was attained when 24 GPS satellites (Block I/II/IIA types) were operating in their assigned orbits, available for navigation use, and providing service. This total included three operational spares in orbit.

Notification of IOC came from the Secretary of Defense following an assessment by the USAF (the system operator) that the constellation could sustain required levels of accuracy and availability throughout the IOC period. IOC occurred on December 8, 1993. Full military FOC is expected in 1995.

Prior to IOC, GPS was considered to be in the process of development for operational purposes, therefore signal availability and accuracy were subject to change.

Operation and logistical support

Starting in 1986, overall operation of the Control and Space Segments of GPS was managed by the USAF 2nd Space Wing at Falcon AFB, Colorado. Prior to that time operation was from a prototype master control station operated from Vandenberg AFB, California.

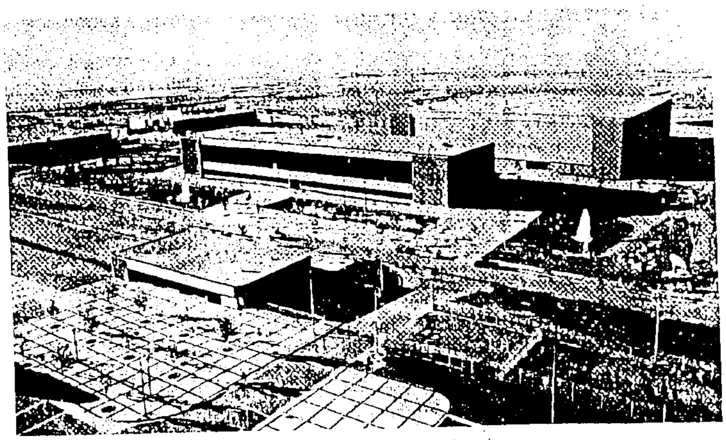

Fig. 1-1. Falcon AFB, Colorado, showing the master control station.

In January 1992 the U.S. Air Force activated the 2nd Operations Squadron (2 SOPS), 50th Space Wing, at Falcon AFB, Colorado, with an assigned mission to operate the master control station (Fig. 1-1).

The costs

The GPS is expensive from the point of view of the United States taxpayer. It is installed, operated, and maintained for all to use, on a worldwide basis, with no user charge.

The overall initial costs to the taxpayer for GPS has been in excess of $10 billion. Annually, additional funds must be expended for system upkeep. The tentative GPS budget for 1994 amounts to more than $500 million for the DOD and various smaller sums for DOT, the USCG, and the FAA.

GPS SEGMENTS

GPS consists of space, control, and user segments. Each segment has specific duties and responsibilities (Fig. 1-2):

- Space—satellites
- Control—ground-based tracking and system adjustment
- User—receiver/processor

Space segment

The NAVSTAR space segment is a constellation (group) of GPS satellites in semi-synchronous orbits around the earth.

Ease Of Use Put Magellan GPS On The Map... Now For Our Next Move.

Introducing the Magellan GPS MAP 7000™ with moving map display. When flying through congested airspace, avoiding traffic and working to stay ahead of your plane, you want a GPS receiver that's easy to use with no double function keys or layers of menus to interpret. The Magellan GPS MAP 7000 combines the power of a GPS moving map with the ease-of-use features Magellan is famous for.

With its customizable navigation screens, fuel and flight planning, VNAV and many other features that pilots demand, the MAP 7000 graphically shows surrounding navaids and class B and C airspace alerts, while navigating on any of the 20 reversible 25-leg flight plans. Just the push of a button displays ground track and speed, bearing and distance to destination, and an adjustable scale CDI in large, easy-to-read characters. And, a built-in Jeppesen® database lets you quickly access VOR and airport information, including graphical runway layouts, lengths, surface and lighting conditions, and frequencies.

Magellan Advantage	Magellan MAP 7000™	II Morrow® Apollo 920
Single Function Keys	YES	NO
Alphanumeric Keypad	YES	NO
Keystrokes Required to		
Set FPLAN PSF - DPA	15	65
Change CDI Scale	1	12
Battery Life	10 Hours	6 Hours
Battery Case Access	Slide Release	Screwdriver
Dimensions	3.5" x 8.6" x 2.1"	1.7" x 7.9" x [illegible]

The MAP 7000 comes with a yoke mount, cigarette lighter adapter, and a detachable antenna, and is completely portable with 10 hours of battery life. Buy the MAP 7000 today and discover why Magellan is the most asked-for name in GPS.

MAGELLAN
WE BRING GPS DOWN TO EARTH™

MAP 7000 is a trademark of Magellan Systems Corporation. Jeppesen is a trademark of Jeppesen, Inc. II Morrow, Inc. is a trademark of United Parcel Service of America, Inc.
For more information, contact: Magellan Systems Corporation, 960 Overland Ct., San Dimas, CA 91773. Ph: (909)394-5000; Fax: (909)394-7050

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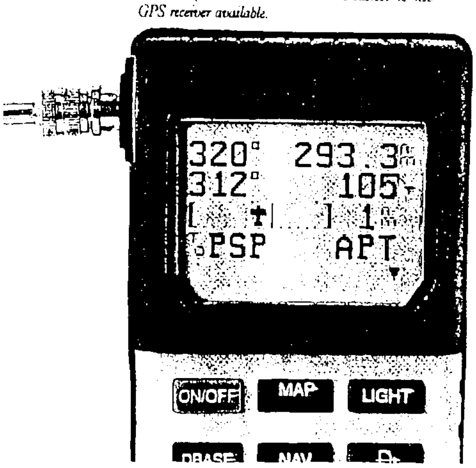
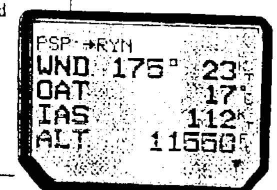
Magellan MAP 7000™
Specifications and Characteristics.

Operating Characteristics

Receiver Type:	5 channels
Time to First Fix (Cold start):	45 seconds
Time to First Fix (Warm start):	30 seconds
Update Rate:	1 second
Maximum Velocity:	951 mph (825 knots)
Maximum Altitude:	58,000 ft./17,678 m
Maximum Acceleration:	2 g
Accuracy (3D)*:	
RMS:	20 m
Velocity:	.1 knots
Waypoints:	500
Routes:	20 reversible
Legs per Route:	25
Navigation functions:	POS, Ground Speed, Track, RNG, BRG, CDI, XTE, ETE, ETA, Wind, Track Angle, Direct To, Moving Map
E6B Functions:	VNAV, Wind, Course, Fuel
Data Output:	RS-232C
Data Format:	NMEA 0183, GAMA Type 1
Map Datums:	14, including 1 user-defined
Airspace:	Class B & C (TCA/ARSA) Alerts
Database: Choice of North America or International (Latin America in both).	Built-in Jeppesen® database of idents and coordinates, frequencies, runway diagrams and info of airports over 1000 ft. in length, and VORs.

Large, bold characters and intuitive navigation screens help make the MAP 7000 the easiest-to-use GPS receiver available.





E6B calculator provides real-time, in-flight information, such as vertical navigation, winds aloft, fuel and route planning.

Physical Characteristics

Size (WxHxD):	3.5" x 8.8" x 2.1"
Weight:	29 ounces (.85 kg)
Display:	Graphics LCD
Case:	Waterproof (it floats)
Operating Temp:	-10°C—60°C (14°F—140°F)
Storage Temp:	-40°C—70°C (-40°F—158°F)
Battery:	6 AA Alkaline or optional NiCad pack
Antenna:	Active detachable, includes suction-cup mount
Yoke Mount:	2.6" x 2.1" x 4.6"

Electrical Characteristics

Battery Life (Continuous):	10 hours—Alkaline 5 hours—NiCad
Input Voltage:	9-35 Vdc
Power Consumption (typical):	130 mA
Backlight on (typical):	175 mA
Accessories:	· AC Adapter (110 V, 220 V, 240 V) · NiCad Battery Pack · NiCad Battery Charger (110 V, 220/240 V, 12 V) · Carrying Case

Unit Includes:

- Yoke Mount
- Power Cable with Cigarette Lighter Adapter
- Antenna
- 6' Coax Cable
- Suction Cup
- Battery Clip
- Manual with Quick Reference Card
- Carrying Strap

For more information, contact: Magellan Systems Corporation, 960 Overland Ct., San Dimas, CA 91773. Ph: (909) 394-5000; Fax: (909) 394-7050

**Accuracy dependent upon HDOP and subject to change in accordance with DOD civil GPS user policy. All Magellan products are made in the U.S.A. and are warranted for a period of one year from date of purchase. See warranty for full details.*

Made in the U.S.A.

MAGELLAN
WE BRING GPS DOWN TO EARTH™

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TrimbleNavigation

AVIONICS PRODUCT

TNL-1000™

Airborne GPS Receiver Navigation System

A low-cost panel mount GPS for general aviation users

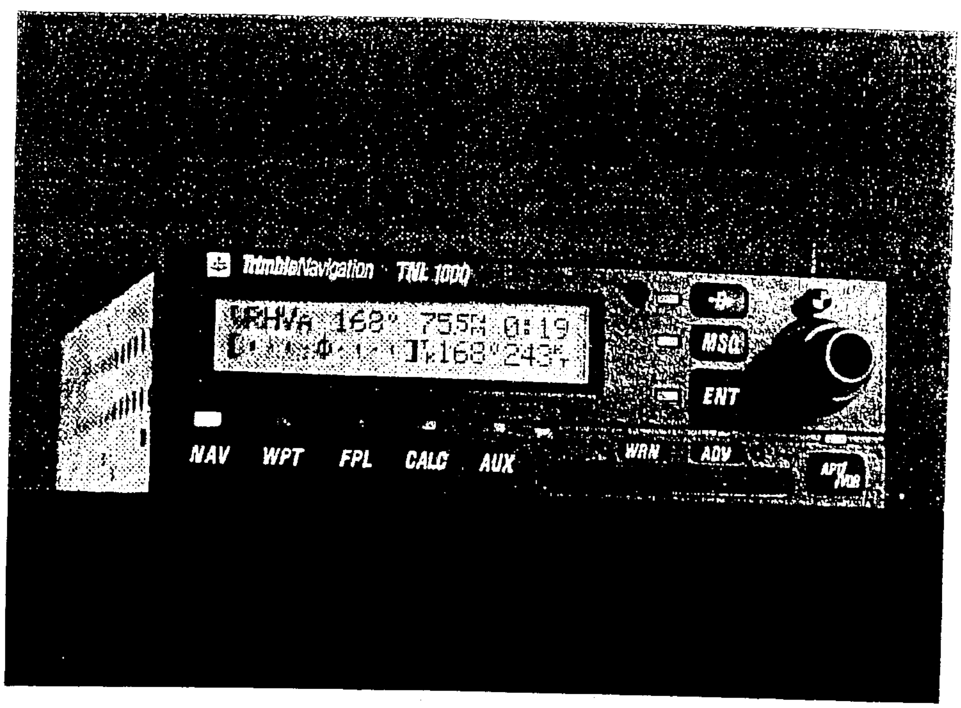
Trimble has taken many of the outstanding features found in its proven GPS Navigator series and packaged them into a very capable and competitively priced GPS navigation system for general aviation operators.

The TNL-1000 provides users with an advanced six-channel continuous parallel tracking receiver which can track up to nine satellites and provide 15 meter RMS position accuracy anywhere in the world. It rapidly calculates a new position and measures speed to a tenth of a knot in all weather conditions.

All the desired navigation features and functions are included in a light weight low-power consumption design. On initialization the TNL-1000 automatically determines your position anywhere on the globe. Navigation information is then instantaneously calculated and displayed on a high contrast super-twist LCD. A destination can be selected from either an internal Jeppesen worldwide data base of airports, VORs, or NDBs, or from one of 250 user-defined waypoints. A front-loading Jeppesen Nav Data card capability is a future upgrade option.

Navigation could not be easier. Just one push of the "Direct-To" button and the TNL-1000 displays your position and shows destination, bearing, distance, ETE, ETA, and cross track error to any way point in the data base and also provides a ground speed and flight track reference on an electronic CDI. You can also create and automatically sequence through 20 flight plans, of 20 waypoints each. Flight plans are easily edited and desired flight routes may be reversed as well. A search feature displays the 20 nearest airports, VORs, NDBs, or user defined waypoints. A calculator mode makes fuel computations easy, determines winds aloft, TAS, and will calculate pressure and density altitude, and much more.

The TNL-1000 is an extremely capable GPS receiver and navigation system that meets or exceeds all applicable industry and Federal Aviation Administration technical, environmental and operational requirements while providing an outstanding value to aviation users.



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GPS Navigator[T] Model 1000

Airborne GPS Navigation System

Features

Worldwide accuracy to 15 meters;* Bright high-contrast backlit LCD 2 x 20 character display; Full three-dimensional positioning; Internal worldwide airport, VOR and NDB aeronautical database; Waypoint library holds up to 250 user-created waypoints; Store up to 20 flight plans of 20 waypoints each; Instantaneous bearing and range to and from any waypoint; Vertical navigation; Interfaces to moving maps, autopilots, CDI, and flags; RS-422 serial output; and 1-year warranty.

System Specifications

Type:	L1 frequency, C/A code, Six-channel receiver, continuous parallel tracking
Acquisition time:	0.5 to 3.5 minutes
Dynamics:	800 knots, (4g tracking)
Accuracy:*	Position: 15 meters RMS Velocity: 0.1 knots steady state Altitude: 35 meters RMS (msl) Time: UTC to nearest microsecond
Computation range:	Great Circle: 0 to 9999 nm
Distance resolution:	0 to 9.99 nm: in 0.01 nm increments 10 to 99.9 nm: in 0.1 nm increments 100 nm +: 1.0 nm increments
Lat/lon resolution:	0.001 minutes
Database:	Internal worldwide Includes airports, VORs and NDB's identifier, Latitude and Longitude
Interfaces:	EIA standards, two RS-422s CDI, flags and ext. annunciators
GPS Antenna:	Omnidirectional flat microstrip with internal preamp.
Display:	High contrast, super-twist LCD backlit, wide temperature range 2 lines of 20 characters each
Environmental:	RTCA DO-160C
Software:	RTCA DO-178A

Physical Characteristics

Receiver Size:	6.3"W x 10.8"D x 2.0"H max.
Antenna:	3.75"W x 4.00"D x 0.75"H
Receiver Weight:	2.4 lbs. (1.1 kg) with mounting tray
Antenna:	0.4 lbs. (0.2 kg)
Power:	10-36 VDC, negative ground 0.35 amps @ 14 VDC 5 watts, 0.21 amps @ 28 VDC 6 watts
Operating temp:	Receiver: -20° to +55°C Antenna: -55° to +70°C
Storage temp:	Receiver: -55° to +70°C
Operating humidity:	95% @ 50°C
Operating Altitude:	Receiver: up to 50,000 feet (cabin pressure) Antenna: up to 50,000 feet

**Note: When Selective Availability (S/A) not implemented. All GPS receivers subject to position and velocity degradation when Department of Defense S/A imposed. GPS Unit complies with U.S. Department of Commerce U.S. GPS Industry Council Export Control Provisions. Specifications subject to change without notice. One Year Warranty. Made in the USA.*

TrimbleNavigation

For Sales Information:
Trimble Navigation
Avionics Division
2105 Donley Drive
Austin, TX 78758
Sales: (512) 873-9100
FAX: (512) 836-9413

For Service & Product Support:
Avionics Division
Product Support: 1-800-487-4662
or (512) 873-9100 Outside U.S.
Service: 1-800-487-4689

THE JEPPESEN MASTER DATABASE

The Jeppesen Master Database is the foundation for all Jeppesen NavData Services. It is a computer library of worldwide navigation information reflecting standard aeronautical information designated by official government aviation authorities. Data entered into the Master Database undergoes extensive computer and manual editing, verification and validation to assure it is the most accurate and reliable navigation data available. Additionally, this is the same Master Database from which Jeppesen charts are produced resulting in a very high degree of correlation between Jeppesen NavData and Jeppesen Airway Manual Services. A brief description of the standard information contained in the Master Database follows.

VHF Navaids: Name, identifier, frequency, class, VOR latitude and longitude, DME latitude and longitude, station declination, DME elevation, frequency protection distance, ILS/DME bias, airport ICAO identifier (ILS/DME only) and other pertinent information for VOR, VOR/DME, VORTAC, DME, TACAN (paired with civil VHF nav frequency), and ILS/DME. Additionally, continuation records are available containing facility characteristics, dynamic magnetic variation, facility elevation and FIR/UIR identifier. Supplemental records are available containing city, state and country served by the navaid.

NDB Navaids: Name, identifier, frequency, class, latitude, longitude, magnetic variation and other pertinent information for non-directional beacons. Additionally, continuation records are available containing facility characteristics, elevation and FIR/UIR identifier. Supplemental records are available containing the city, state and country served by the navaid.

Airways: Route identifier, fix identifier, fix description (function), route type, level (high/low altitude), direction restrictions, cruising table identifier, outbound magnetic course, route segment distance, inbound magnetic course, minimum altitude, maximum altitude and other pertinent information for government-designated airways worldwide.

Enroute Waypoints: Identifier, name or description, type, usage, latitude, longitude, dynamic magnetic variation and other pertinent information for enroute on- and off-airway intersections and other waypoints worldwide. Additionally, continuation records are available containing the FIR/UIR identifier.

Airway Markers: Identifier, name, marker code, marker shape, power, latitude, longitude, minor axis, magnetic variation, facility elevation and other pertinent information for enroute airway markers worldwide.

Holding Patterns: Fix identifier, inbound holding course, turn direction, leg length or leg time, altitude and other pertinent information for enroute holding patterns worldwide.

Cruising Tables: Identifier, course from, course to, magnetic/true indicator, cruise level from, vertical separation, cruise level to and other pertinent information for standard and non-standard IFR enroute cruising level tables.

Minimum Off-Route Altitudes (MORAs): MORAs for one degree grids of latitude and longitude worldwide. MORAs for 1/2-degree grids are available in selected areas.

Flight Information Regions (FIR/UIR): Identifier, name, lateral and vertical description of boundaries, communications address, adjacent FIR/UIR, ATC speed and altitude reporting units, entry report requirements, cruising table identifier and other information for Flight Information Regions (FIR) and Upper Flight Information Regions (UIR) worldwide. 01373

Restrictive Airspace: Restriction type, identification number or name, active times, vertical and lateral boundaries, controlling agency and other pertinent information for alert, caution, danger, military operations, prohibited, restricted, training and warning areas.

Continued on other side

Controlled Airspace: Airspace type, airspace center, lateral and vertical boundaries, name and other pertinent information for Terminal Control Areas (TCA) and Airport Radar Service Areas (ARSA).

Airports: ICAO and ATA/IATA identifiers, name, longest runway length, IFR capability, airport reference point, latitude and longitude, magnetic variation, elevation, speed limit and speed limit altitude, recommended VHF navaid and other pertinent information for IFR and VFR airports throughout the world. *Supplemental records are available containing city, state, and country served, TCA/ARSA indicator, fuel, oxygen, and repairs availability, landing fee, traffic pattern altitude, time zone and other information.

Runways: Airport ICAO identifier, runway identifier, length, width, magnetic bearing, threshold latitude and longitude, threshold elevation, displaced threshold distance, threshold crossing height, localizer identifier, stop-way length and other pertinent information for most runways worldwide. Additionally, continuation records are available containing runway true bearing, source and touchdown zone elevation. *Supplemental records are available containing runway surface, lighting, takeoff and landing lengths and other information.

Terminal Waypoints: Identifier, name or description, type, usage, latitude, longitude, dynamic magnetic variation and other pertinent information for intersections and other waypoints required to support Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARs) and standard instrument approaches worldwide. Additionally, continuation records are available containing the FIR/UIR identifier.

Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARs), and Standard Instrument Approaches: Airport ICAO identifier, SID identifier, route type, transition identifier, waypoint identifier, waypoint description, turn direction, route segment path and termination, recommended VHF navaid, waypoint bearing and distance from the recommended VHF navaid, outbound magnetic course, route distance, holding distance or time, crossing altitude description, altitude, transition altitude, speed limit, vertical angle and other pertinent information for each route segment for most government-published SIDs, STARs and Approaches worldwide. Additionally, continuation records are available containing the route segment length.

ILS Localizer/Glide Slope Facilities: Airport ICAO identifier, localizer identifier, ILS category, localizer frequency, runway identifier, localizer latitude and longitude, localizer bearing, glide slope latitude and longitude, localizer and glide slope positions with reference to runway, localizer width, glide slope angle, station declination, glide slope height at landing threshold, glide slope facility elevation and other pertinent information for ILS localizer and glide slope facilities worldwide. Additionally, continuation records are available containing facility characteristics, localizer true bearing, true bearing source and glide slope beam width.

ILS Markers: Airport ICAO identifier, localizer identifier, marker type, locator frequency, runway identifier, marker latitude and longitude, minor axis, locator latitude and longitude, class, facility characteristics, locator identifier, magnetic variation, facility elevation and other pertinent information for ILS Markers worldwide.

Minimum Sector Altitudes (MSAs): Airport ICAO identifier, MSA center, radius limit, sector bearings, sector altitudes and other pertinent information for MSAs worldwide.

Airport Communications: Airport identifier, communications type, radar availability, receive/transmit indicator, traffic advisory availability, frequency, latitude and longitude, magnetic variation, facility elevation, 24 hour or part-time operation, frequency sectorization and altitudes, associated navaid, call name and other pertinent information for airport communications facilities.

***Enroute Communications:** Communications type, identifier, frequency, receive/transmit indicator, radar availability, latitude and longitude, magnetic variation, facility elevation, 24 hour or part-time operation, frequency altitudes, associated navaid and other pertinent information for Air Route Traffic Control Centers (ARTCC), Flight Information Regions (FIR/UIR) and Flight Service Stations (FSS).

*Currently available in North America. Planned for development worldwide.

NavData

Trusted Worldwide

BASELINE UPDATE SERVICE

Baseline Update Service is a customer defined data service delivered in ARINC Specification 424 format, the world standard. Geographic area of coverage and data content are selected by each customer from the entire range of information available in the worldwide Jeppesen Master Data Base. Geographic coverage area can be chosen by standard ICAO geographic areas or customer defined rectangles using latitude/longitude coordinates. Information content within each area is selected by data type with a large number of options available. All of this flexibility is available to ensure that the NavData delivered is not only the most complete and accurate available, but also that it meets the specific requirements of each individual customer.

Test and Trial NavData are available for evaluation and development of NavData capabilities. Test NavData is a sample data base containing examples of each record type from pre-defined geographic areas. Trial NavData is available to customers developing the capability to use Jeppesen NavData. Geographic area and data content are defined by the customer for Trial NavData.

Service Specifications

Application:	Flight Navigation, Flight Planning, Flight Simulation, Special Applications
Geographic Area:	Customer Selection/Worldwide Available
Data Content:	Customer Selection
Data Format:	ARINC Specification 424
Update Frequency:	Every 28 Days
Deliverables:	Nine-Track Magnetic Tape, 3½ and 5¼ inch disk, and Man-readable Paper Printout

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NavData

Trusted Worldwide

U.S. Department of the Interior
U.S. Geological Survey
Earth Science
Information Center (ESIC)

Factsheet

US GeoData
Digital Elevation Models

Digital elevation models

Digital elevation model (DEM) data consist of an array of regularly spaced elevations. U.S. Geological Survey (USGS) DEM data are sold in 7.5-minute, 15-minute (Alaska only), and 1-degree units.

Data production

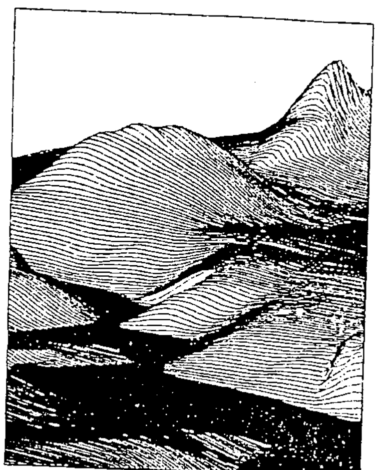
DEM data for 7.5-minute units are collected by four production methods: (1) the Gestalt Photo Mapper II (GPM2), an automated photogrammetric system designed to produce orthophotos, digital terrain data, and contours in subunits called patches; (2) manual profiling from photogrammetric stereomodels using stereoplotters equipped with three-axis electronic digital profile recording modules, by scanning stereomodels along successive terrain profiles; (3) interpolation of the elevations from stereomodel digitized contours, derived from stereoplotters equipped with three-axis digital recording modules used for compilation of 7.5-minute topographic quadrangle maps; and (4) interpolation from digital line graph (DLG) hypsographic and hydrographic data, collected using scanners, manual digitizers, and automated line followers.

DEM data for 15-minute units are derived from DLG hypsographic and hydrographic data.

DEM data for 1-degree units are collected from topographic map sources, ranging from the 7.5-minute map series to the 1- by 2-degree map series, or from photographic sources by using image correlation systems.

Unit size and file extent

DEM data for 7.5-minute units correspond to the USGS 7.5-minute topographic quadrangle map series for all of the United States and its territories except Alaska.



Portion of a 7.5-minute DEM plot of Tumwater, WA

DEM data for 15-minute units correspond to the USGS 15-minute topographic quadrangle map series in Alaska. The unit sizes in Alaska vary depending on the latitude. Units south of 59° N. cover 15- by 20-minute areas, those between 59° and 62° N. cover 15- by 22.5-minute areas, those between 62° and 68° N. cover 15- by 30-minute areas, and those north of 68° N. cover 15- by 36-minute areas. (All values are latitude-longitude, respectively.)

DEM data are produced by the Defense Mapping Agency in 1- by 1-degree units that correspond to the east or west half of USGS 1- by 2-degree topographic quadrangle map series (1:250,000 scale) for all of the United States and its territories. In Alaska these are west, central, and east files.

All nonstandard quadrangles with neatlines that extend beyond the standard unit size to accommodate overedge boundaries are collected as multiples of the standard unit sizes. These data, therefore, are sold as two 7.5- by 7.5-minute units.

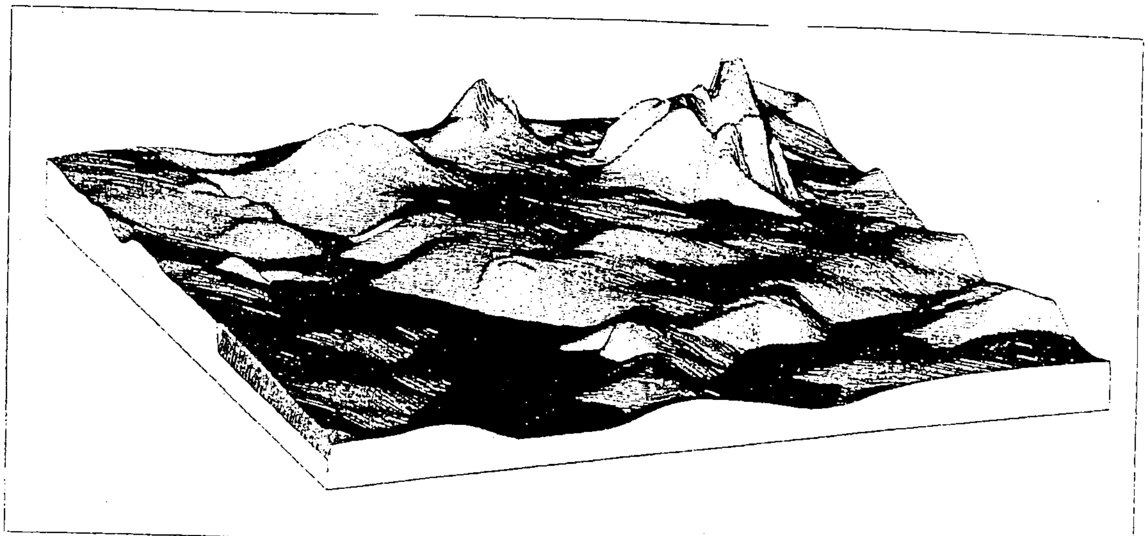
Data characteristics

All DEM data are similar in logical data structure and are ordered from south to north in profiles that are ordered from west to east. However, they differ in geographic reference systems and sampling intervals.

DEM data in 7.5-minute units consist of regular arrays of elevations arranged horizontally on the Universal Transverse Mercator (UTM) coordinate system of the North American Datum of 1927 (NAD 27). These data are stored as profiles with 30-meter spacing along and between each profile. The profiles do not always have the same number of elevations because of the variable angle between true north and grid north in the UTM system.

DEM data in 15-minute units consist of regular arrays of elevations arranged horizontally to the coordinate system of NAD 27. The spacing between elevations along profiles is 2 arc seconds of latitude by 3 arc seconds of longitude. Each profile has 451 elevations.

DEM data in 1-degree units consist of a regular array of elevations arranged horizontally using the coordinate system of the World Geodetic System 1972 Datum. A few units are also available using the World Geodetic System 1984 Datum. Spacing of the elevations along and between each profile is 3 arc seconds with 1,201 elevations per profile. The only exception is DEM data in Alaska, where the spacing and number of elevations per profile varies depending on the latitude. Latitudes between 50° and 70° N. have spacings at 6 arc seconds with 601 elevations per profile, and latitudes greater than 70° N. have spacings at 9 arc seconds with 401 elevations per profile.



7.5 - Minute DEM plot of Tumwater, Washington

Data records

A DEM file is organized into three logical records, types A, B, and C. The type A record contains information defining the general characteristics of the DEM, including its name, boundaries, units of measurement, minimum and maximum elevations, number of type B records, and projection parameters. There is only one type A record per DEM file. The type B record contains profiles of elevation data and associated header information. There is a type B record for each profile. The type C record contains statistics on the accuracy of the data.

Data accuracy

The accuracy of DEM data depends on the source and resolution of the data samples. The accuracy of the 7.5-minute DEM data is derived by comparing linear interpolated elevations in the DEM with corresponding map location elevations and computing the statistical standard deviation or root-mean-square error (RMSE). The RMSE is used to describe the DEM accuracy. The vertical accuracy of 7.5-minute DEM's is 15 meters or better. The 15-minute DEM accuracy is one-half of a contour interval of the 15-minute topographic quadrangle map or better. The 1-degree DEM data have an absolute accuracy of 130 meters horizontally and 30 meters vertically.

US GeoData Sampler

A US GeoData Sampler is available for a nominal charge. The sampler includes the 7.5-minute DEM and the 1:24,000-scale DLG for Tumwater, Washington; the 1:100,000-scale DLG for Tacoma, Washington; the 1:2,000,000-scale DLG for the northwestern States (WA, OR, and ID); 1- by 2-degree land use and land cover data for Seattle, Washington; the 1- by 1-degree DEM for Seattle, Washington East; and the Geographic Names Information System data for the State of Washington.

Ordering instructions

DEM data are written as ANSI-standard ASCII characters in fixed-block format on unlabeled or ANSI labeled 9-track magnetic tapes at a 1,600-bpi or 6,250-bpi density. The logical record length is 1,024 bytes with a physical record size of 4,096 bytes or four logical records. DEM data may be ordered by specifying the unit size, maximum block size, tape density, and tape label and by identifying the sales unit by topographic quadrangle name or by the southeast latitude and longitude corner coordinates.

The US GeoData Sampler can be ordered in standard or optional ASCII DLG formats, on either one 6,250-bpi or three 1,600-bpi tapes.

The Earth Science Information Center can furnish indexes, price lists, and order forms. Data Users Guides are included with each order.

For further information, contact:

U.S. Geological Survey
Earth Science Information Center
507 National Center
Reston, Virginia 22092
1-800-USA-MAPS

01377

7.5-MINUTE DIGITAL ELEVATION MODELS

Characteristics

A 7.5-minute DEM has the following characteristics:

- The data consist of a regular array of elevations referenced horizontally in the UTM coordinate system. The reference datum may be North American Datum of 1927 (NAD 27), North American Datum of 1983 (NAD 83), Old Hawaiian Datum (OHD), or Puerto Rico Datum of 1940 (PRD).

- The unit of coverage is the 7.5-minute quadrangle. Overedge coverage is not provided.

- The data are ordered from south to north in profiles that are ordered from west to east.

- The data are stored as profiles in which the spacing of the elevations along and between each profile is 30 m.

- The profiles do not always have the same number of elevations because of the variable angle between the quadrangle's true north and the grid north of the UTM coordinate system.

- Elevations for the continental U.S. are either meters or feet referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Elevations for Hawaii and Puerto Rico are either in meters or feet referenced to local mean sea level. DEM's of low-relief terrain or generated from contour maps with intervals of 10 ft (3 m) or less are generally recorded in feet. DEM's of moderate to high-relief terrain or generated from maps with terrain contour intervals greater than 10 ft are generally recorded in meters.

Profiles for 7.5-minute DEM's are generated by using a UTM cartesian coordinate system as a base. The profiles are clipped to the straight-line intercept between the four geographic corners of the quadrangle--an approximation of the geographic map boundary (neatline). The resulting area of coverage for the DEM is a quadrilateral, the opposite sides of which are not parallel.

The UTM coordinates of the four corners (bounds) of the DEM's are listed in the type A record, as shown in table 1,* data element 11; the UTM coordinates of the starting points of each profile are listed in the type B record (profiles), table 2,* data element 3. These coordinates describe the shape of the quadrilateral and the variable x, y starting position of each profile. Because of the variable orientation of the quadrilateral in relation to the UTM coordinate system, profiles intersect the east and west neatlines as well as the north and south neatlines. In addition, DEM's have profile easting values that are continuous from one DEM to the adjoining DEM only if the adjoining DEM is contained within the same UTM zone.

* See Data Users Guide 5 - Digital Elevation Models

MAIL ROOM JUL 11 1994 PAT. & TRADEMARK OFF.

In the United States Patent and Trademark Office 274394

Mailed 11 July 1994

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Sir:

Please file the following enclosed patent application papers:

Applicant #1, Name: Jed Margolin

Applicant #2, Name: ______

Title: PILOT AID USING SYNTHETIC REALITY

[✓] Specification, Claims, and Abstract: Nr. of Sheets 36

[✓] Declaration: Date Signed: 10 July 1994

[✓] Drawing(s): Nr. of Sheets Enc.:(In Triplicate): Formal: 13 Informal: ___

[✓] Small Entity Declaration of Inventor(s) [ ] SED of Non-Inventor/Assignment/Licensee

[ ] Assignment; please record and return; recordal fee enclosed.

Check for $ 355 for:

[✓] $ 355 for filing fee (not more than three independent claims and twenty total claims are presented).

[ ] $______ Additional if Assignment is enclosed for recordal.

[✓] Return Receipt Postcard Addressed to Applicant #1.

[✓] **Request Under MPEP § 707.07(j):** The undersigned, a pro-se applicant, respectfully requests that if the Examiner finds patentable subject matter disclosed in this application but feels that Applicant's present claims are not entirely suitable, the Examiner draft one or more allowable claims for applicant.

Very respectfully,

Jed Margolin
Applicant #1 Signature

______
Applicant #2 Signature

3570 Pleasant Echo Dr.
Address (Send Correspondence Here)

San Jose, CA 95148-1916

______
Address

Express Mail Label # EF981868779US ; **Date of Deposit** 11 July 1994

I hereby certify that this paper or fee is being deposited with the United States Postal Service using "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to "Commissioner of Patents and Trademarks, Washington, DC 20231."

Signed: Jed Margolin
Inventor

01379

In the United States Patent and Trademark Office
Information Disclosure Statement

[illegible]ed [illegible]lin Pilot Aid using Synthetic Reality

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Sir:

Attached are completed Form PTO-1449 and copies of the pertinent parts of the references cited thereon. Following are comments on these references pursuant to Rule 98:

The 1984 patent to Taylor et al. (U.S. Patent No. 4,445,118) shows the basic operation of the global positioning system (GPS).

The 1984 patent to Johnson et al. (U.S. Patent No. 4,468,793) shows a receiver for receiving GPS signals.

The 1984 patent to Maher (U.S. Patent No. 4,485,383) shows another receiver for receiving GPS signals.

The 1986 patent to Evans (U.S. Patent No. 4,599,620) shows a method for determining the orientation of a moving object and producing roll, pitch, and yaw information.

The 1992 patent to Timothy et al. (U.S. Patent No. 5,101,356) also shows a method for determining the orientation of a moving object and producing roll, pitch, and yaw information.

The 1993 patent to Ward et al. (U.S. Patent No. 5,185,610) shows a method for determining the orientation of a moving object from a single GPS receiver and producing roll, pitch, and yaw information.

The 1992 patent to Fraughton et al. (U.S. Patent No. 5,153,836) shows a navigation, surveillance, emergency location, and collision avoidance system and method whereby each craft determines its own position using LORAN or GPS and transmits it on a radio channel along with the craft's identification information. Each craft also receives the radio channel and thereby can determine the position and identification of other craft in the vicinity.

The 1992 patent to Beckwith et al. (U.S. Patent No. 5,140,532) provides a topographical two-dimensional real-time display of the terrain over which the aircraft is passing, and a slope-shading technique incorporated into the system provides to the display an apparent three-dimensional effect similar to that provided by a relief map. This is accomplished by reading compressed terrain data from a cassette tape in a controlled manner based on the instantaneous geographical location of the aircraft as provided by the aircraft navigational computer system, reconstructing the compressed data by suitable processing and writing the reconstructed data into a scene memory with a north-up orientation. A read control circuit then controls the read-out of data from the scene memory with a heading-up orientation to provide a real-time display of the terrain over which the aircraft is passing. A symbol at the center of display position depicts the location of the aircraft with respect to the terrain, permitting the pilot to navigate the aircraft even under conditions of poor visibility. However, the display provided by this system is in the form of a moving map rather than a true perspective display of the terrain as it would appear to the pilot through the window of the aircraft.

The 1987 patent to Beckwith et al. (U.S. Patent No. 4,660,157) is similar to U.S. Patent No. 5,140,532. It also reads compressed terrain data from a cassette tape in a controlled manner based on the instantaneous geographical location of the aircraft as provided by the aircraft navigational computer system and reconstructs the compressed data by suitable processing and writing the reconstructed data into a scene memory. However, instead of providing a topographical two-dimensional display of the terrain over which the aircraft is passing and using a slope-shading technique to provide an apparent three-dimensional effect similar to that provided by a relief map as shown in the '532 patent, the '157 patent processes the data to provide a 3D perspective on the display. There are a number of differences between the '157 patent and the present invention:

1. The '157 Patent stores the map as a collection of terrain points with associated altitudes; the large amount of storage required by this approach requires that a tape be prepared for each mission.
   The present invention stores terrain data as a collection of polygons which results in a significant reduction of data base storage; larger geographic areas can be stored so that it it not necessary to generate a data base for each mission.
2. The '157 Patent uses a tape cassette for data base storage; the long access time for tape storage makes it necessary to use a relatively large cache memory. The present invention uses a CD-ROM which permits random access to the data so that the requirements for cache storage are reduced.
3. The '157 Patent accounts for the aircraft's heading by controlling the way the data is read out from the tape. Different heading angles result in the data being read from a different sequence of addresses. Since addresses exist only at discrete locations, the truncation of address locations causes an unavoidable change in the map shapes as the aircraft changes heading. The present invention stores terrain as polygons which are mathematically rotated as the aircraft changes attitude. The resolution is determined by number of bits used to represent the vertices of the polygons, not the number of storage addresses.
4. The '157 accounts for the roll attitude of the aircraft by mathematically rotating the screen data after it is projected. The '157 Patent does not show the display being responsive to the pitch angle of

the aircraft. In systems such as this the lack of fidelity is apparent to the user. People know what things are supposed to look like and how they are supposed to change perspective when they move. The present invention uses techniques that have long been used by the computer graphics industry to perform the mathematically correct transformation and projection.

5. The '157 shows only a single cockpit display while one of the embodiments of the present invention shows a stereographic head-mounted display with a head sensor. The pilot is presented with a synthesized view of the world that is responsive to wherever the pilot looks; the view is not blocked by the cockpit or other aircraft structures. This embodiment is not anticipated by the '157 patent.

The 1991 patent to Behensky et al. (U.S. Patent No. 5,005,148) shows a driving simulator for a video game. The road and other terrain are produced by mathematically transforming a three-dimensional polygon data base.

The first sales brochure from Atari Games Corp. is for a coin-operated game (Hard Drivin') produced in 1989 and relates to the '148 patent. The terrain is represented by polygons in a three-dimensional space. Each polygon is transformed mathematically according to the position and orientation of the player. After being tested to determine whether it is visible and having the appropriate illumination function performed, it is clipped and projected onto the display screen. These operations are in general use by the computer graphics industry and are well known to those possessing ordinary skill in the art.

The second sales brochure from Atari Games Corp. is for a coin-operated game (Steel Talons) produced in 1991 and which also relates to the '148 patent and the use of polygons to represent terrain and other objects.

In the United States Patent and Trademark Office
Information Disclosure Statement

The 1993 patent to Dawson et al. (U.S. Patent No. 5,179,638) shows a a method and apparatus for providing a texture mapped perspective view for digital map systems which includes a geometry engine that receives the elevation posts scanned from the cache memory by the shape address generator. A tiling engine is then used to transform the elevation posts into three-dimensional polygons. There are a number of differences between the '638 patent and the present invention:

1. The '638 Patent is for a digital map system only. The matter of how the location and attitude are selected is not addressed. The present invention uses a digital map as part of a system for presenting an aircraft pilot with a synthesized view of the world regardless of the actual visibility.
2. The '638 Patent stores the map as a collection of terrain points with associated altitudes, thereby requiring a large amount of data storage. The terrain points are transformed into polygons during program run-time, thereby adding to the processing burden. The present invention stores terrain data as a collection of polygons which results in a significant reduction of data base storage.
3. The present invention also teaches the use of a stereographic head-mounted display with a head sensor. The pilot is presented with a synthesized view of the world that is responsive to wherever the pilot looks; the view is not blocked by the cockpit or other aircraft structures. This embodiment is not anticipated by the '638 patent.

The 1994 patent to Hamilton et al. (U.S. Patent No. 5,296,854) shows a helicopter virtual display system in which the structual outlines corresponding to structual members forming the canopy structure are added to the head-up display in order to replace the canopy structure clues used by pilots which would otherwise be lost by the use of the head-up display.

The 1994 patent to Lewins (U.S. Patent No. 5,302,964) shows a head-up display for an aircraft and incorporates a cathode-ray tube image generator with a digital look-up table for distortion correction. An optical system projects an image formed on the CRT screen onto a holographic mirror combiner which is transparent to the pilot's direct view through the aircraft windshield.

The sales brochure from the Polhemus company shows the commercial availability of a position and orientation sensor which can be used on a head-mounted display.

The article from EDN magazine, January 7, 1993, pages 31-42, entitled "System revolutionizes surveying and navigation" is an overview of how the global positioning system (GPS) works and lists several manufacturers of commercially available receivers. The article also mentions several applications such as the use by geologists to monitor fault lines, by oil companies for off-shore oil explorations, for keeping track of lower-orbit satellites, by fleet vehicle operators to keep track of their fleet, for crop sprayers to spread fertilizer and pesticides more efficiently, and for in-car systems to display maps for automotive navigation.

The section from "Aviator's Guide to GPS" presents a history of the GPS program.

In the United States Patent and Trademark Office
Information Disclosure Statement

The sales brochure from Megellan Systems Corp. is for commercially available equipment comprising a GPS receiver with a moving map display. The map that is displayed is a flat map.

The sales brochure from Trimble Navigation is for a commercially available GPS receiver.

The sales brochure from the U.S. Geological Service shows the availability of Digital Elevation Models for all of the United States and its territories.

The second sales brochure from the U.S. Geological Service shows the availability of Digital Line Graph Models for all of the United States and its territories. The data includes: political and administrative boundaries; hydrography consisting of all flowing water, standing water, and wetlands; major transportation systems consisting of roads and trails, railroads, pipelines, transmission lines, and airports; and significant manmade structures.

The Washington Sectional Aeronautical Chart is a paper map published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, that shows the complexity of the information that an aircraft pilot needs in order to fly in the area covered by the map. The other areas of the U.S. are covered by similar maps.

In the United States Patent and Trademark Office
Information Disclosure Statement

The sales brochure from Jeppesen Sanderson shows that the company makes its navigation data base available in computer readable form.

Very respectfully,

Jed Margolin

Jed Margolin

Applicant Pro Se

July 10, 1994
3570 Pleasant Echo
San Jose, CA 95148
(408) 238-4564

ENC: List of Prior Art & References

Sheet 1 of 6 08-513,298

LIST OF PRIOR ART CITED BY APPLICANT	ATTY DOCKET NO.	SERIAL NO. ~~08/274,394~~
	APPLICANT Jed Margolin	
	FILING DATE 07/11/94	GROUP 2304

U.S. PATENT DOCUMENTS

Examiner Initial		Document Number	Date	Name	Class	Subclass	Filing Date If Appl.
TN	AA	4,445,118	04/84	Taylor et al.	342	357	
TN	AB	4,468,793	08/84	Johnson et al.	375	97	
TN	AC	4,485,383	11/84	Maher	342	352	
TN	AD	4,599,620	07/86	Evans	342	357	
TN	AE	5,101,356	03/92	Timothy et al.	364	449	
TN	AF	5,185,610	02/93	Ward et al.	342	357	
TN	AG	5,153,836	10/92	Fraughton et al.	364	461	
TN	AH	5,140,532	08/92	Beckwith et al.	395	101	
TN	AI	4,660,157	04/87	Beckwith et al.	364	522	
TN	AJ	5,005,148	04/91	Behensky et al.	364	578	
TN	AK	5,179,638	01/93	Dawson et al.	395	125	

FOREIGN PATENT DOCUMENTS

		Document Number	Date	Country	Class	Subclass	Translation Yes	No
	AL							
	AM							

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, etc.)

TN	AR	John Gallant, EDN magazine; January 7, 1993; pages 31-42 " System revolutionizes surveying and navigation "
TN	AS	Bill Clarke; Aviator's Guide to GPS; 1994; pages 2 and 3 " GPS Program History"

EXAMINER	DATE CONSIDERED
Tan Nguyen	11/06/94

Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

LIST OF PRIOR ART CITED BY APPLICANT	ATTY DOCKET NO.	SERIAL NO. 08/274,394
	APPLICANT Jed Margolin	
	FILING DATE 07/11/94	GROUP 2304

U.S. PATENT DOCUMENTS

Examiner Initial		Document Number	Date	Name	Class	Subclass	Filing Date If Appl.
TN	AA	5,296,854	03/94	Hamilton et al.	340	980	
TN	AB	5,302,964	04/94	Lewins	345	7	
	AC						
	AD						
	AE						
	AF						
	AG						
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	AI						
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	AK						

FOREIGN PATENT DOCUMENTS

		Document Number	Date	Country	Class	Subclass	Translation Yes	No
	AL							
	AM							

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, etc.)

TN	AR	Magellan Systems Corp, 960 Overland Ct, San Dimas, CA 91773 Sales brochure for GPS receiver with moving map display (MAP 7000), Jan 1994
TN	AS	Trimble Navigation; 2105 Donley Dr, Austin TX 78758 Sales brochure for Airborne GPS receiver (TNL-1000) (No date is available)

EXAMINER	DATE CONSIDERED
Tan Nguyen	11/08/94

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 08-513,298

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	APPLICANT Jed Margolin	
	FILING DATE 07/11/94	GROUP 2304

U.S. PATENT DOCUMENTS

Examiner Initial		Document Number	Date	Name	Class	Subclass	Filing Date If Appl.
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FOREIGN PATENT DOCUMENTS

		Document Number	Date	Country	Class	Subclass	Translation Yes No
	AL						
	AM						

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, etc.)

TN	AR	Jeppesen Sanderson, Inc; 55 Inverness Drive East, Englewood, CO 80112 Sales brochure for navigation data base in computer readable form
TN	AS	U.S. Geological Service, Earth Science Information Center, Menlo Park, CA Sales brochure for Digital Elevation Model data, June 1993

EXAMINER Tan Nguyen	DATE CONSIDERED 11/06/94

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	AA						
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	AK						

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		Document Number	Date	Country	Class	Subclass	Translation Yes	Translation No
	AL							
	AM							

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, etc.)

TN	AR	U.S. Geological Service, Earth Science Information Center, Menlo Park, CA Sales brochure for Digital Line Graph data , June 93
TN	AS	U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington Aeronautical Chart (paper map)

EXAMINER	DATE CONSIDERED
Tan Nguyen	11/06/94

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FOREIGN PATENT DOCUMENTS

		Document Number	Date	Country	Class	Subclass	Translation Yes	No
	AL							
	AM							

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, etc.)

TN	AR	Polhemus, P.O.Box 560, Colchester, VT Sales brochure for 3D head tracker, Jan 1994
TN	AS	Atari Games Corp, 675 Sycamore Dr, Milpitas, CA 95035; Sales brochure for coin-operated video game with 3D polygon-based graphics (Hard Drivin'), 1988

EXAMINER	DATE CONSIDERED
Tan Nguyen	11/08/94

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	AM							

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, etc.)

TN	AR	Atari Games Corp, 675 Sycamore Dr, Milpitas, CA 95035; Sales brochure for coin-operated video game with 3D polygon-based graphics (Steel Talons), 1991
	AS	

EXAMINER Jan Nguyen	DATE CONSIDERED 11/06/94

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GPS RECEIVERS

System revolutionizes surveying and navigation

JOHN GALLANT, Technical Editor

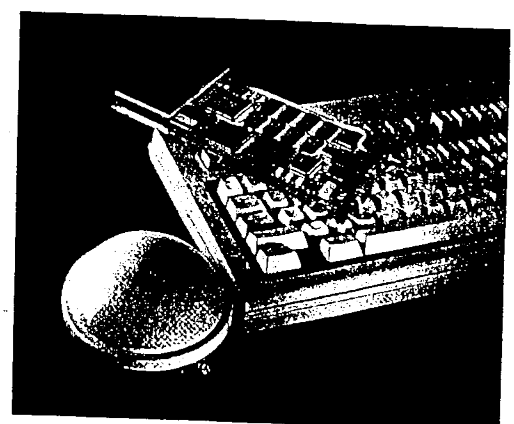
Science began when people looked to the skies to track the seasons and find their way. Today's engineers have achieved a satellite-based system that can determine your position to within a centimeter.

The Global Positioning System (GPS) is a radio-navigation system that employs RF transmitters in 24 satellites. GPS receivers decode the satellites' signals to calculate the latitude, longitude, and altitude of a position on earth. The positioning accuracy ranges from 40m to less than 1 cm. This description seems straightforward, but imagine the possibilities.

GPS applications appear limitless (see Table 1). You'll be designing them into surveying and navigational equipment, airplanes, boats, and trucks—and that's just for starters.

Already GPS receivers on airplanes and boats are providing accuracies 10 to 100 times better than those achieved by ground-based radio-navigation aids such as Loran, Omega, and VOR/VME Tacan. Geologists are using GPS to monitor fault lines. Oil companies are using GPS for offshore oil exploration. Because of their high-altitude orbit, GPS satellites can keep track of lower-orbit satellites such as weather satellites. Fleet vehicles are trading their squawking radios for GPS receivers so the home office can track vehicles in metropolitan areas.

Satlock Inc (Stanfield, AZ) is using the GPS to help crop sprayers spread fertilizer and pesticides more effectively. A GPS receiver monitors the sprayed area to prevent overspraying and overfertilization. As receiver costs plummet, there's no reason why every automobile shouldn't soon have a GPS receiver to determine an optimal route to a destination. An in-car computer would analyze the GPS data and present the route in color on a video screen. Information on popular tourist attractions and restaurants could be stored in CD-ROM. In fact, Etak (Sunnyvale, CA) already offers digital maps for automotive navigation.



Tapping into the GPS can be as easy as plugging a GPSCard into your PC and connecting it to the Model 501 GPSAntenna and integrated low-noise amplifier. The Novatel card has 10 channels that track the C/A code and carrier signal's phase.

Taxpayers foot the bill

The GPS, officially known as the NAVSTAR GPS (NAVigation System with Timing And Ranging Global Positioning System), is nearing completion thanks to US taxpayers and the Department of Defense (DoD). For complete and continuous global coverage, the GPS requires 21 satellites and 3 spares circling the earth once every 12 hours. The orbits are 10,898 nautical miles above the earth and are arranged in six orbital planes (Fig 1). The planes are inclined 55° with respect to the earth's equatorial plane. At the date of this writing, 19 satellites are actively deployed. The launch schedule should complete the 24-satellite constellation in 1993.

Table 1—Representative GPS receivers

Company	Model	Applications	Housing	Price	Features
[illegible]	M-XII receiver	Surveying	[illegible] case, [illegible] lbs	$16,800 (Prism software); $8000	Receives L1, L2, C/A code and P code; 12 parallel channels; 2-minute cold start to first data; 8-line, 4-character display; 2 RS-232C ports; 12W from 10 to 36V dc supply; 1-PPS output; −20 to +55°C
	OEM [illegible] GPS receiver	OEM part	[illegible] RF module, [illegible]	$2500 to $5000, depending on options	Receives L1, C/A code; 12 parallel channels; 3-minute cold start to first data; 1-sec updates; NMEA 183 interface; 2 RS-232C ports; 4W [illegible]
Canadian Marconi Co	CMA 3012	Airborne navigation	2.6×8.5×9.5-in. RF module, 7 lbs	$17,250	Receives L1, C/A code; 12 parallel channels; 11 ARINC 429 ports; 2 RS-232C ports; conforms to MIL-STD-810; 20W from 18 to 36V dc supply; −55 to +70°C
Garmin [illegible]	GPS [illegible]	Marine navigation	[illegible] handheld unit with battery pack, 19 oz	$1419	Multitrac operating system tracks 8 satellites continuously; 250 waypoints; 101 map datums; NMEA 183 interface; 1.1W from battery pack; backlit dot-matrix LCD; 1-sec updates; waterproof; −15 to +70°C
	GPS 100 MRN	Portable navigation	6.25×3.95×2-in. handheld unit, 25 oz	$1795	Multitrac operating system tracks 8 satellites continuously; 2 minutes to first fix; 1-sec updates; NMEA 183 interface; 250 waypoints; −15 to +70°C
Magellan Systems Corp	NAV 5000D	Marine navigation	3.5×8.8×2.1-in. handheld unit	$1200	5 parallel channels; 55 sec from cold start to first fix; NMEA 183 interface; 100 waypoints, 12 map datums; 4-line, 16-character LCD; RTCM SC-104 differential corrections; −10 to +60°C.
Magnavox GPS [illegible]	GPS Engine	OEM part	2.5×5.83-in. card [illegible]	$500 to $1100	Receives L1, C/A code; 8 parallel channels; 1 minute to first fix; 1-sec updates; RTCM SC-104 differential corrections; 1.5W from 6.5V dc supply; 1W from 5V dc supply; −20 to +70°C
Marcor	AVL-2	Vehicle location	6.91×6.38×3.05-in. waterproof enclosure, 1.6 lbs	$1399	2 parallel channels; tracks 8 satellites; Adaptive Kalman filter; 7 to 20 minutes from cold start to first fix; RS-232C port; NMEA 183 interface; 15W from 10 to 40V dc supply; −30 to +70°C.
Motorola [illegible]	6-channel parallel receiver	OEM part	[illegible]×2.76-in. card, [illegible]	$500 (OEM)	Receives L1, C/A code; 6 parallel channels; RS-232C port; 1-sec updates; 49 datums; 1.3W from 5V supply; 1.8W from 12V supply; Microstrip antenna powered by receiver; −30 to +80°C
Novatel Communications Ltd	GPScard Performance Series	OEM part	8-bit ISA bus card or Eurocard	$4390 (Model 911 with RTCM differential correction)	Receives L1, C/A code; 10 parallel channels; NMEA 183 interface; 1-PPS output; 68 datums; 2 RS-232C ports; 2-minutes from cold start to first fix; 200-msec updates; 6W
Odetics [illegible]	ISA [illegible]	Time synchronizations	ISA bus, VME bus, SBus, VAX BI and Nubus, Micro Channel Architecture board	$3995 to $13,995, depending on bus	5 parallel channels; generates IRIG A, IRIG B, XR3, NASA 36 and 2137 time codes; TTL outputs are 100k, 10k, 100, 10, 1PPS; time accuracy ±1 μsec; receives Universal Coordinate Time (UTC) from GPS satellites
Rockwell International Corp	Navcore V	OEM port	2.65×4-in. card, 4 oz	$395 (100)	Receives L1, C/A code; 5 parallel channels; 1-sec updates; 1.6W; −40 to +85°C (high-temp version).
Sercel Inc [illegible]	NR106	Surveying	10.83×5.31×10.80-in. waterproof case, 13.89 lbs	$12,600	Receives L1, C/A code; 10 parallel channels; 0.6-sec updates; RTCM SC104 differential correction; 2 minutes from cold start to first fix; 2 RS-232C ports; NMEA 183 interface; stores 10 stations in permanent memory; 12W from 10 to 36V dc supply; −10 to +55°C
Trimble Navigation	System Surveyor 4000SE	Surveying	9.8×11×4-in. case, 6 lbs	$17,950; options ranging from $1250 to $2350	Receives L1, C/A code; 8 parallel channels; 2 RS-232C ports; RTCM SC104 differential corrections; 4-line, 40-character LCD; NMEA 183 interface; 1-PPS output; 5W from 10 to 35V dc supply; −20 to +55°C.
	TNL-3000	GPS and Loran navigation	6.25×10.8×2-in. unit, 2.75 lbs	$6795	Receives L1, C/A code; 6 parallel channels; 1-sec updates; RS-422 port; 2-line, 20-character LED display; Multichain Loran operation; All Loran chains available; 250 waypoints; 12W from 10 to 32V dc supply; −20 to +55°C.

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GPS RECEIVERS

The satellite configuration guarantees that a GPS receiver located anywhere on earth can receive RF signals from at least four satellites 24 hours a day. Each satellite transmits unique biphase pseudo-random-noise codes on two L-band carrier frequencies—1575.42 and 1227.60 MHz. (For definitions of GPS terms, see **box**, "Glossary of GPS terms.") A GPS receiver decodes the spread-spectrum modulations and uses triangulation techniques on the satellite signals to determine its precise longitude, latitude, and altitude.

The spherical error probability (SEP) defines the radius of a sphere in which a GPS receiver's calculated position has a 50% confidence level. The DoD has a worldwide position-accuracy goal of 15m SEP using pseudorange measurements. (Because synchronization errors exist between the transmitter and re-

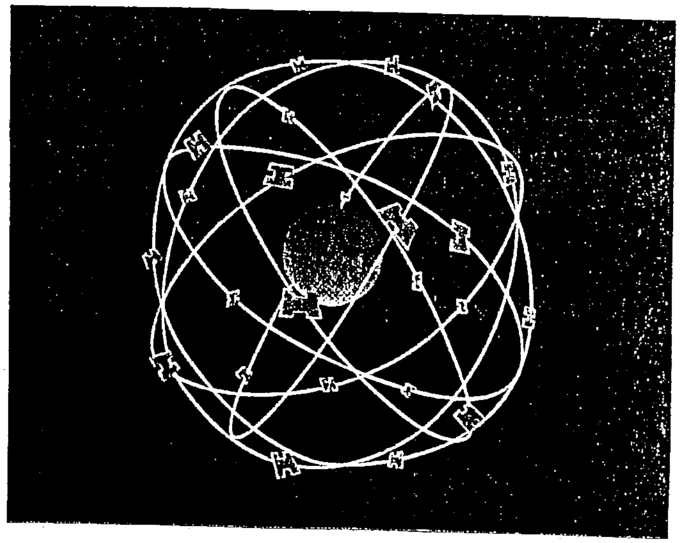

Fig 1—The complete Global Positioning System will include 21 satellites plus three spares traveling in 12-hour circular orbits 10,898 nautical miles above the earth's surface. There are six orbital planes, which are inclined 55° from the earth's equatorial plane.

For more information . . .

For more information on the GPS receivers discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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Suite 750
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ceiver clocks, the pseudorange is not the true range. See box, "Finding your pseudoway," for how to convert the pseudorange to the true range.)

The GPS was conceived in the 1970s because of the insufficient coverage and inherent inaccuracies of the 1960's Transit system. This system—which is still operational—consists of five or six satellites in polar orbits 580 nautical miles above the earth. Transit is accurate to within 500m and does not include enough satellites to provide global coverage.

The DoD maintains the GPS via five monitor stations. The stations

Glossary of GPS terms

Biphase modulation—A phase-shift-keying technique that changes the phase of the carrier frequency by 180° on each bit transition in a data sequence.

C/A code (Coarse/Acquisition code)—A sequence of pseudorandom binary bits that biphase-modulates the L1 satellite carrier frequency. The code has a switching rate of 1.023 MHz and repeats every 1023 bits.

Datum—A surveying term that describes how to position and orient a surveying matrix on the earth's surface.

Differential GPS—An accuracy-enhancing technique that employs two GPS receivers at two different locations. The receivers exchange data with each other in real time to eliminate ephemeris and clock errors.

Ephemeris—A set of parameters defining the orbit of a satellite. A GPS satellite broadcasts these parameters in a navigation message that modulates the two carrier signals. Six parameters define a smooth elliptical orbit in which a satellite's position is a function of time relative to a reference time. Additional parameters describe the deviation of the satellite's motion from the smooth ellipse. (The plural is "ephemerides.")

GDOP (Geometrical Dilution Of Precision)—A figure of merit for the range-measurement accuracy of a specific satellite configuration. The lower the GDOP, the greater the accuracy. The GDOP calculated by GPS receivers determines the optimal satellite selection which changes with time.

NAVSTAR GPS (NAVigation System with Timing And Ranging Global Positioning System)—A satellite-based radio-navigation system financed by the US Department of Defense (DoD). The GPS consists of 21 satellites plus three spares, arranged in six orbits 10,898 miles above the earth. Using the satellites' signals, a GPS receiver can calculate its longitude, latitude, and altitude. The system provides continuous global coverage to an unlimited number of users.

L band—The band of frequencies extending from 1 to 2 GHz. Both the L1 and L2 carrier frequencies GPS satellites transmit to receivers are in the L band. The frequencies are 1575.42 and 1227.60 MHz, respectively.

P code (Precision code)—A sequence of pseudorandom binary bits that biphase-modulates both satellite carrier frequencies. The frequency is 10.23 MHz, and the sequence repeats every 266.4 days. A unique segment of the code is assigned to each satellite and resets each week. The P code is primarily for military purposes.

Pseudorange—The distance between a transmitter and a receiver based on measuring the elapsed time for 1-way transmission and multiplying by the speed of light. Because synchronization errors exist between the transmitter and receiver clocks, the pseudorange is not the true range.

RTCM (Radio Technical Committee for Maritime Applications)—A Department of Transportation committee that defines data-exchange protocols and message formats for differential navigation corrections.

S band—The band of frequencies extending from 2 to 4 GHz. The GPS control station at Colorado Springs, CO, communicates with the satellites via an S-band uplink at 2227.50 MHz. The station sends tracking and telemetry data and command signals. The downlink from the satellites to the control station is at the ostensible S-band frequency of 1783.74 MHz.

SA (Selective Availability)—The DoD's method for denying civilian GPS receivers the same accuracy as military receivers. The DoD purposely degrades the resolution of the ephemerides data and dithers the C/A code's frequency to degrade a receiver's navigation accuracy from approximately 15m SEP without SA to approximately 40m SEP with SA.

SEP (Spherical Error Probability)—The radius of a sphere that defines a 50% confidence level in the accuracy of a position measurement in three dimensions—latitude, longitude, and altitude. The 2-dimensional analogue for latitude and longitude measurements is the CEP (circular error probability).

Waypoint—An intermediate latitude and longitude point on a navigated course. The navigator must pass the point to reach the final destination. A waypoint can be moving or stationary.

WGS-84 (World Geodetic System 1984)—The standard coordinate system adopted for the GPS. The system is a best-fit approximation of the earth's surface to an oblate spheroid. The latitudes and longitudes of the spheroid are used with local maps to determine the contours of a particular region.

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are in Hawaii and Kwajalein in the Pacific ocean, the Ascension Islands in the Atlantic ocean, Diego Garcia in the Indian ocean, and Colorado Springs, CO. The Colorado Springs location is the master control station for the system. All of the monitor stations track the GPS satellites, and the master control station provides 24-hour updates to correct for satellites' ephemerides and clock errors. ("Ephemerides" is an astronomical term for tables of parameters defining the orbit of a satellite.) The master control station commu-

Finding your pseudoway

The Global Positioning System (GPS) calculates the latitude, longitude, and altitude of any point on earth using 1-way radio navigation. Conventional 2-way radio-navigation systems determine distance by measuring the time of arrival or phase difference between a transmitted signal and a received echo signal. Because the signal traverses the distance twice, the range to the reflector is $c\Delta t/2$, where c is the speed of light and t is time.

Two-way radio navigation is impractical for a satellite-based system because of the potential interference when millions of user signals simultaneously try to use the satellites as reflectors or transponders. Therefore, the GPS determines position by transmitting information on two L-band carrier frequencies, L1 and L2. Transmission is in one direction only—from the satellite to a ground or airborne receiver. The accuracy of this 1-way scheme depends on the synchronization between the satellite and receiver clocks. These clocks, in turn, are synchronous with an atomic GPS time standard kept at the master control station.

The satellites modulate the carrier frequencies with two biphase pseudorandom-noise (PRN) waveforms and a biphase navigation message. The bit rates of the modulations are submultiples of the carrier frequencies and shift the carrier phase 180° on each bit transition.

Cross correlation measures time delay

One of the PRN waveforms is the Coarse/Acquisition (C/A) code. The C/A code, also known as the civilian code, modulates the L1 carrier at 1.023 MHz. The code comprises a sequence of 1023 pseudorandom bits, which repeat every millisecond. Each GSP satellite broadcasts a unique C/A code. The codes are orthogonal, so their cross correlations are nearly zero.

The other PRN waveform is the Precise, or Protected, code (P code), which the US military uses. The P code modulates both carrier frequencies at 10.23 MHz and repeats about every 266.4 days. Each GPS satellite has a unique 1-week segment of the P code, which resets each week.

The navigation message modulates both carrier frequencies at 50 bps and contains 1500 bits, which repeat every 30 seconds. Each satellite's navigation message contains information about the accuracy of the satellite's clock, the satellite's ephemeris, the condition of the satellite, and low-accuracy almanac data. By representing the C/A code as C(t), the P code as P(t), and the navigation message data as D(t), you can express the two L-band satellite signals as

$$L1(t) = P(t)D(t)\cos(f_{L1}t) + C(t)D(t)\sin(f_{L1}t)$$

$$L2(t) = P(t)D(t)\cos(f_{L2}t),$$

where f_{L1} is the L1 carrier frequency of 1575.42 MHz, and f_{L2} is the L2 carrier frequency of 1227.60 MHz. Actually, only the L1 carrier frequency is necessary to determine position. Dual-frequency receivers use the L2 carrier frequency primarily to compensate for atmospheric effects.

Civilian receivers use the C/A code. To determine the distance between the receiver and a particular satellite, the receiver generates a replica of the satellite's C/A code using its onboard synchronized clock. A cross-correlator delays the receiver-generated code to align it in time with the C/A code from the satellite. When the codes align, a peak in the correlator's output lets the receiver determine how long ago the code was sent, or the time delay. The receiver and satellite clocks are synchronous, so the receiver can deduce the distance from the time delay: Distance = speed of light × time delay.

Pseudorange contains clock errors

This distance is called the pseudorange because it contains clock-synchronization errors. Incorporating the clock-error term (t_{ERROR}), the pseudorange is given by

$$\text{Pseudorange} = \rho + c\Delta t_{ERROR},$$

where ρ is the true range, which equals the speed of light times the change in the GPS master-control-station clock.

The clock-error term is the difference between the satellite-clock error (δt_S) and the receiver clock error (δt_R):

$$\Delta t_{ERROR} = \Delta t_S - \Delta t_R.$$

The satellites use rubidium and cesium atomic clocks that have long-term frequency stabilities of 10^{-13}/day.

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