

AO 120 (Rev. 08/10)

TO: Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
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In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Eastern District of Texas, Marshall Division on the following

☐ Trademarks or ☒ Patents. (☐ the patent action involves 35 U.S.C. § 292.);

DOCKET NO. 2:22-cv-00351-RWS-R	DATE FILED 9/9/2022	U.S. DISTRICT COURT Eastern District of Texas, Marshall Division
PLAINTIFF Textron Innovations Inc.		DEFENDANT SZ DJI Technology Co., Ltd., DJI Europe B.V., SZ DJI Baiwang Technology Co. Ltd., and iFlight Technology Company Ltd.
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1 10,275,950	4/30/2019	Textron Innovations Inc.
2 8,332,082	12/11/2012	Textron Innovations Inc.
3 8,682,505	3/25/2014	Textron Innovations Inc.
4 11,288,972	3/29/2022	Textron Innovations Inc.
5		

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
2		
3		
4		
5		

In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE
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Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director
Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/711,234	03/25/2014	8682505	0837RF-H793-C	1159

38441 7590 03/05/2014
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

KEVIN THOMAS CHRISTENSEN, Plano, TX;
SHYHPYNG JACK SHUE, Grapevine, TX;
TROY SHELDON CAUDILL, Burleson, TX;
BELL HELICOPTER TEXTRON INC., Fort Worth, TX

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
 or **Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

38441 7590 11/01/2013
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below. *via EFS-Web.*

James E. Walton	(Depositor's name)
<i>James E. Walton</i>	(Signature)
3 February 2014	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/711,234	12/11/2012	KEVIN THOMAS CHRISTENSEN	0837RF-H793-C	1159

TITLE OF INVENTION: FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1780	\$300	\$0	\$2080	02/03/2014

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, TAN QUANG	3661	701-003000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

- (1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
 (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1. James E. Walton
 2. Richard G. Eldredge
 3.

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

Textron Innovations Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Providence, Rhode Island

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☒ Issue Fee
☒ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☒ Payment by credit card. Form PTO-2638 is attached. - Paid via EFS-Web.
☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 502806 (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
- ☐ Applicant asserting small entity status. See 37 CFR 1.27
- ☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see form PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature

James E. Walton

Date 3 February 2014

Typed or printed name

James E. Walton

Registration No. 47,245

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Electronic Patent Application Fee Transmittal

Application Number:	13711234			
Filing Date:	11-Dec-2012			
Title of Invention:	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS			
First Named Inventor/Applicant Name:	KEVIN THOMAS CHRISTENSEN			
Filer:	James Edward Walton			
Attorney Docket Number:	0837RF-H793-C			
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	1501	1	960	960
Publ. Fee- Early, Voluntary, or Normal	1504	1	0	0

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				960

Electronic Acknowledgement Receipt

EFS ID:	18092559
Application Number:	13711234
International Application Number:	
Confirmation Number:	1159
Title of Invention:	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS
First Named Inventor/Applicant Name:	KEVIN THOMAS CHRISTENSEN
Customer Number:	38441
Filer:	James Edward Walton
Filer Authorized By:	
Attorney Docket Number:	0837RF-H793-C
Receipt Date:	03-FEB-2014
Filing Date:	11-DEC-2012
Time Stamp:	12:06:31
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$ 960
RAM confirmation Number	9686
Deposit Account	502806
Authorized User	WALTON, JAMES E

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	PTOL-85-20140203.pdf	153155 b0222957bdf365430bb3300ee946f08f43c961e5	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	32174 7678bdd134de9dcf8eb3ff46f1f48ae67ec603b0	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			185329		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/711,234	12/11/2012	KEVIN THOMAS CHRISTENSEN	0837RF-H793-C

CONFIRMATION NO. 1159

PUBLICATION NOTICE



OC000000066208914

38441
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

Title: FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Publication No. US-2014-0025237-A1

Publication Date: 01/23/2014

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently <http://www.uspto.gov/patft/>.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently <http://pair.uspto.gov/>. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

38441 7590 11/01/2013
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

EXAMINER

NGUYEN, TAN QUANG

ART UNIT

PAPER NUMBER

3661

DATE MAILED: 11/01/2013

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
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13/711,234

12/11/2012

KEVIN THOMAS CHRISTENSEN

0837RF-H793-C

1159

TITLE OF INVENTION: FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1780	\$300	\$0	\$2080	02/03/2014

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

38441 7590 11/01/2013
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/711,234	12/11/2012	KEVIN THOMAS CHRISTENSEN	0837RF-H793-C	1159

TITLE OF INVENTION: FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1780	\$300	\$0	\$2080	02/03/2014

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, TAN QUANG	3661	701-003000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363). ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached. ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.	2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 1 _____ 2 _____ 3 _____
---	---

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see form PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/711,234	12/11/2012	KEVIN THOMAS CHRISTENSEN	0837RF-H793-C	1159

38441 7590 11/01/2013
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

EXAMINER

NGUYEN, TAN QUANG

ART UNIT PAPER NUMBER

3661

DATE MAILED: 11/01/2013

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

**Notices of Allowance and Fee(s) Due mailed between October 1, 2013 and
December 31, 2013**

(Addendum to PTOL-85)

If the “Notice of Allowance and Fee(s) Due” has a mailing date on or after October 1, 2013 and before January 1, 2014, the following information is applicable to this application.

If the issue fee is being timely paid on or after January 1, 2014, the amount due is the issue fee and publication fee in effect January 1, 2014. On January 1, 2014, the issue fees set forth in 37 CFR 1.18 decrease significantly and the publication fee set forth in 37 CFR 1.18(d)(1) decreases to \$0.

If an issue fee or publication fee has been previously paid in this application, applicant is not entitled to a refund of the difference between the amount paid and the amount in effect on January 1, 2014.

Notice of Allowability	Application No. 13/711,234	Applicant(s) CHRISTENSEN ET AL.	
	Examiner TAN Q. NGUYEN	Art Unit 3661	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to 10/16/2013.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are 1-20. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

- a) ☐ All b) ☐ Some *c) ☐ None of the:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.

THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.
Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

- | | |
|--|---|
| 1. ☐ Notice of References Cited (PTO-892) | 5. ☐ Examiner's Amendment/Comment |
| 2. ☐ Information Disclosure Statements (PTO/SB/08),
Paper No./Mail Date _____ | 6. ☐ Examiner's Statement of Reasons for Allowance |
| 3. ☐ Examiner's Comment Regarding Requirement for Deposit
of Biological Material | 7. ☐ Other _____. |
| 4. ☐ Interview Summary (PTO-413),
Paper No./Mail Date _____. | |

/TAN Q NGUYEN/
Primary Examiner, Art Unit 3661

Issue Classification 	Application/Control No. 13/711,234	Applicant(s)/Patent under Reexamination CHRISTENSEN ET AL.
	Examiner TAN Q. NGUYEN	Art Unit 3661

ISSUE CLASSIFICATION													
ORIGINAL				INTERNATIONAL CLASSIFICATION									
CLASS		SUBCLASS		CLAIMED				NON-CLAIMED					
701		3		G	05	D	1	/08	G	06	F	7	/00
CROSS REFERENCES				B	64	C	19	/00					/
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)												
701	4	7						/					/
244	180							/					/
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-----		/TAN Q NGUYEN/ October 23, 2013		Total Claims Allowed: 20	
(Assistant Examiner)	(Date)			O.G. Print Claim(s)	O.G. Print Fig.
(Legal Instruments Examiner)	(Date)	(Primary Examiner)	(Date)	1	9

☒ Claims renumbered in the same order as presented by applicant					☐ CPA		☐ T.D.		☐ R.1.47		
Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		31		61		91		121		181
	2		32		62		92		122		182
	3		33		63		93		123		183
	4		34		64		94		124		184
	5		35		65		95		125		185
	6		36		66		96		126		186
	7		37		67		97		127		187
	8		38		68		98		128		188
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	27		57		87		117		147		207
	28		58		88		118		148		208
	29		59		89		119		149		209
	30		60		90		120		150		210

Index of Claims



Application/Control No.

13/711,234

Examiner

TAN Q. NGUYEN

Applicant(s)/Patent under Reexamination

CHRISTENSEN ET AL.

Art Unit

3661

✓	Rejected
=	Allowed

—	(Through numeral) Cancelled
÷	Restricted

N	Non-Elected
I	Interference

A	Appeal
O	Objected

Claim		Date									
Final	Original	7/11/13	10/23/13								
1	1	✓	=								
2	2	✓	=								
3	3	✓	=								
4	4	✓	=								
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6	6	✓	=								
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EAST Search History

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	39	control\$6 same aircraft\$3 same lateral\$3 same longitudinal\$3 same head\$4 same (ground\$3 surfac\$3 terrain\$3 level\$4)	US-PGPUB; USPAT; UPAD	OR	ON	2013/10/23 10:21
L2	4	1 same turn\$3 same yaw\$6	US-PGPUB; USPAT; UPAD	OR	ON	2013/10/23 10:21

10/ 23/ 2013 10:22:10 AM
C:\ Users\ tnguyen2\ Documents\ EAST\ Workspaces\ 13-711234 Control helicopter using long and lateral control.wsp

Search Notes

Application/Control No.

13/711,234

Examiner

TAN Q. NGUYEN

Applicant(s)/Patent under
Reexamination

CHRISTENSEN ET AL.

Art Unit

3661

SEARCHED

Class	Subclass	Date	Examiner
701	3,4,7 14,301	7/2/2013	TN
244	180,181	7/2/2013	TN
340	979	7/2/2013	TN
updated	searches	10/23/2013	TN

INTERFERENCE SEARCHED

Class	Subclass	Date	Examiner
701	3,4,7	10/23/2013	TN
244	180	10/23/2013	TN

**SEARCH NOTES
(INCLUDING SEARCH STRATEGY)**

	DATE	EXMR
PLUS SEARCH	6/28/2013	TN
EAST SEARCH	7/1/2013	TN
Interference Search History Printout	10/23/2013	TN



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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/711,234	12/11/2012	KEVIN THOMAS CHRISTENSEN	0837RF-H793-C

38441
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

CONFIRMATION NO. 1159
NEW OR REVISED PPD NOTICE



NOTICE OF NEW OR REVISED PROJECTED PUBLICATION DATE

The above-identified application has a new or revised projected publication date. The current projected publication date for this application is 01/23/2014. If this is a new projected publication date (there was no previous projected publication date), the application has been cleared by Licensing & Review or a secrecy order has been rescinded and the application is now in the publication queue.

If this is a revised projected publication date (one that is different from a previously communicated projected publication date), the publication date has been revised due to processing delays in the USPTO or the abandonment and subsequent revival of an application. The application is anticipated to be published on a date that is more than six weeks different from the originally-projected publication date.

More detailed publication information is available through the private side of Patent Application Information Retrieval (PAIR) System. The direct link to access PAIR is currently <http://pair.uspto.gov>. Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Questions relating to this Notice should be directed to the Office of Data Management, Application Assistance Unit at (571) 272-4000, or (571) 272-4200, or 1-888-786-0101.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: 13/711,234

Filed: 11 DECEMBER 2012

For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

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Examiner: NGUYEN, TAN QUANG

Art Unit: 3661

Confirmation No. 1159

AMENDMENT

Filed via EFS-Web

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Amendment is being filed in response to the Office Action dated 17 July 2013, which provides for a three-month response period ending 17 October 2013.

Please enter the following amendments and consider the following remarks.

CERTIFICATE OF TRANSMISSION UNDER 37 C.F.R. § 1.8(a)(1)(i)(C)
Date of Transmission: <u>10/16/13</u>
I hereby certify that this correspondence is being transmitted to the U.S. Patent and Trademark Office (USPTO) via the USPTO electronic filing system (EFS-Web) on the date shown above.
By: <u>James E. Walton</u> James E. Walton

IN THE CLAIMS:

The following is a complete listing of the claims. Please amend the claims as follows.

1. **(Currently Amended)** A control system for an aircraft, comprising:
a lateral control architecture configured to control lateral motion of the aircraft;
and
a longitudinal control architecture configured to control longitudinal motion of the aircraft;
wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface; and
wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading.
2. **(Original)** The control system of claim 1, wherein the control system is operably associated with a directional controller manually manipulated by a pilot.
3. **(Original)** The control system of claim 2, further comprising:
a directional control architecture, having:
a directional heading control loop;
a directional turn coordination control loop; and
a directional yaw rate control loop.
4. **(Original)** The control system of claim 3, further comprising:
a directional control latch in data communication with the directional control architecture;
wherein, as the directional controller is moved out of a detent position, the directional control latch activates a constant vector flat turn motion.

5. **(Original)** The control system of claim 1, the lateral control architecture comprising:

- a lateral sideward groundspeed control loop;
- a lateral roll attitude control loop; and
- a lateral roll rate control loop.

6. **(Original)** The control system of claim 5, further comprising:

a lateral controller carried by the aircraft, the lateral controller being manipulated by a pilot controlling the aircraft, the lateral controller creating a lateral command in data communication with the lateral sideward groundspeed control loop, the lateral roll attitude control loop, and the lateral roll rate control loop.

7. **(Original)** The control system of claim 6, further comprising:

a lateral control hatch in data communication with the control system;
wherein, as the lateral controller is moved out of a detent position, the lateral control hatch resets a lateral speed hold.

8. **(Original)** The control system of claim 1, the longitudinal control architecture comprising:

- a longitudinal forward speed control loop;
- a longitudinal pitch angle control loop; and
- a longitudinal pitch rate control loop.

9. **(Original)** The control system of claim 8, the longitudinal control architecture further comprising:

a longitudinal controller carried by the aircraft, the longitudinal controller being manipulated by a pilot controlling the aircraft, the longitudinal controller creating a longitudinal command in data communication with the longitudinal forward speed control loop, the longitudinal pitch angle control loop, and the longitudinal pitch rate control loop.

10. **(Original)** The control system of claim 9, further comprising:
a longitudinal control latch in data communication with the control system;
wherein, as the longitudinal controller is moved out of a detent position, the longitudinal control latch resets a longitudinal speed hold.
11. **(Currently Amended)** A method, comprising:
sensing a directional movement of [[a]] an aircraft;
determining lateral and longitudinal movements of the aircraft; and
selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface;
wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading.
12. **(Original)** The method of claim 11, the method further comprising:
commanding the flat yaw movement with a directional controller manipulated by a pilot controlling the aircraft.
13. **(Original)** The method of claim 12, wherein controlling the flat yaw movement comprises:
communicating data through a directional heading control loop;
communicating data through a directional turn coordination control loop; and
communicating data through a directional yaw rate control loop.
14. **(Original)** The method of claim 12, further comprising:
activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position.
15. **(Original)** The method of claim 11, wherein determining lateral movements is achieved through the method comprising:
communicating lateral motion data through a lateral sideward groundspeed control loop;

communicating lateral motion data through a lateral roll attitude control loop; and
communicating lateral motion data through a lateral roll rate control loop.

16. **(Original)** The method of claim 11, further comprising:
controlling lateral movement with a lateral controller manipulated by a pilot
controlling the aircraft.
17. **(Original)** The aircraft of claim 16, further comprising:
resetting a lateral speed hold with a lateral control hatch as the lateral controller
is moved out of a detent position.
18. **(Original)** The method of claim 17, wherein controlling longitudinal movement
includes the method comprising:
communicating longitudinal motion data through a longitudinal forward speed
control loop;
communicating longitudinal motion data through a longitudinal pitch angle control
loop; and
communicating longitudinal motion data through a longitudinal pitch rate control
loop.
19. **(Original)** The aircraft of claim 11, further comprising:
controlling longitudinal movement with a longitudinal controller manipulated by a
pilot controlling the aircraft.
20. **(Original)** The aircraft of claim 19, further comprising:
resetting a longitudinal speed hold with a longitudinal control hatch as the
longitudinal controller is moved out of a detent position.

The Applicants submit that the foregoing amendments add no new matter to the
application.

REMARKS:

Claims 1-20 are currently pending in the present application.

Claims 1-20 stand rejected under 35 USC § 102(e) as being anticipated by Piasecki (2010/0324758).

In view of the following comments, allowance of all the claims pending in the application is respectfully requested.

Rejections Under 35 U.S.C. § 102(e):

Claims 1-20 stand rejected under 35 USC § 102(e) as being anticipated by Piasecki. The Applicants respectfully traverse this rejection for at least the following reasons.

Claim 1 is hereby amended by further clarifying that the control system is configured to continuously control the yaw movement of the aircraft during flight while also maintaining a constant vector heading. Support for these amendments is found in at least paragraph 0013 and FIG. 2 in the drawings. FIG. A below is taken from FIG. 2 in the drawings, and depicts the movement of the aircraft during flight. As shown, the aircraft moves in a constant heading indicated by arrow D1 while the aircraft turns in the yaw-direction.

The Examiner states that these features are discussed in at least FIGS. 5-7, 10, and 11 along with the corresponding text in Piasecki. The Applicants respectfully disagree. Although Piasecki does disclose a system that utilizes lateral and longitudinal motions, the art is silent with respect to using these movements along with maintaining a constant vector heading, as clearly shown in the present application. As such, the Applicants respectfully request that the rejections be reconsidered in view of these amendments and remarks, and that Claim 1, along with dependent Claims 2-10 be allowed.

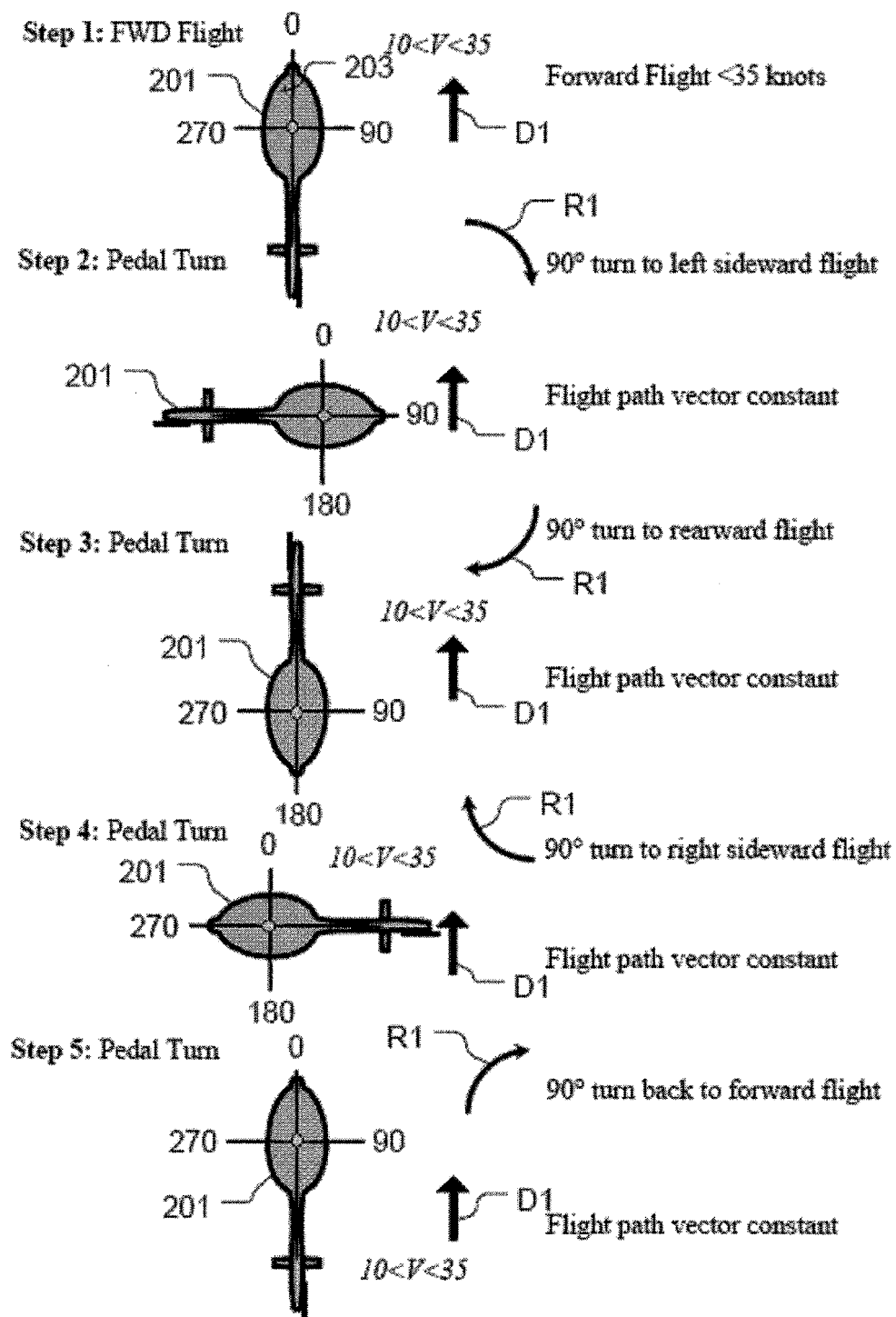


FIG. A: the claimed control system shown in FIG. 2 of the drawings.

With respect to Claims 11-20, the features discussed herein are also incorporated with independent Claim 11. Thus, the Applicants respectfully request that the rejections to these claims also be reconsidered and withdrawn in view of the foregoing amendments and remark, and that Claims 11-20 be allowed.

Distinctions, Other Than Those Discussed, May Exist:

It should be noted that the Applicants have merely discussed example distinctions from the various references cited by the Examiner. Other distinctions may exist and Applicants reserve the right to discuss these additional distinctions in a future Response or on Appeal. By not responding to any additional statements made by the Examiner, the Applicants do not acquiesce to any of the Examiner's additional statements. The Applicants respectfully submit that the remarks provided above are sufficient to overcome the Examiner's rejections.

CONCLUSION:

The Applicants respectfully submit that the subject application is now in condition for allowance, and an early reconsideration and issuance of a Notice of Allowance are earnestly solicited. The Examiner is invited to contact the undersigned at (817) 447-9955 with any questions, comments, or suggestions relating to the referenced patent application.

This Amendment is being filed via the U.S. Patent and Trademark Office's EFS-Web electronic filing system. No fees are deemed to be necessary; however, the Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayments, to **Deposit Account No. 502806**.

Respectfully submitted,

10/16/13
Date

James E. Walton
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1169 N. Burleson Blvd., Suite 107-328
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(817) 447-9955 (Voice)
(817) 447-9954 (Facsimile)
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CUSTOMER NO. 38441

ATTORNEY FOR APPLICANTS

Electronic Acknowledgement Receipt

EFS ID:	17141931
Application Number:	13711234
International Application Number:	
Confirmation Number:	1159
Title of Invention:	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS
First Named Inventor/Applicant Name:	KEVIN THOMAS CHRISTENSEN
Customer Number:	38441
Filer:	James Edward Walton
Filer Authorized By:	
Attorney Docket Number:	0837RF-H793-C
Receipt Date:	16-OCT-2013
Filing Date:	11-DEC-2012
Time Stamp:	14:26:12
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Amendment20131016.pdf	691284 c48eabbd44af4f5fd50f2763edd7ebefe71d34b2	yes	11

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Miscellaneous Incoming Letter	1	2
	Amendment/Req. Reconsideration-After Non-Final Reject	3	11
Warnings:			
Information:			
Total Files Size (in bytes):		691284	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: 13/711,234

Filed: 11 DECEMBER 2012

For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

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§

Examiner: NGUYEN, TAN QUANG

Art Unit: 3661

Confirmation No. 1159

TRANSMITTAL

Filed via EFS-Web

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Sir:

Please file the following enclosed documents in the subject application:

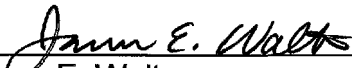
1. This Transmittal with Certificate of Transmission; and
2. Amendment.

CERTIFICATE OF TRANSMISSION UNDER 37 C.F.R. § 1.8(a)(1)(i)(C)	
Date of Transmission:	10/16/13
I hereby certify that this correspondence is being transmitted to the U.S. Patent and Trademark Office (USPTO) via the USPTO electronic filing system (EFS-Web) on the date shown above.	
By:	 James E. Walton

The foregoing documents are being filed via the U.S. Patent and Trademark Office's EFS-Web electronic filing system. No fees are deemed to be necessary; however, the undersigned hereby authorizes the Commissioner to charge any fees that may be required, or credit any overpayments, to **Deposit Account No. 502806**.

Respectfully submitted,

Date 10/16/13


James E. Walton
Reg. No. 47,245
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1169 N. Burleson Blvd., Suite 107-328
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CUSTOMER NO. 38441

ATTORNEY FOR APPLICANTS

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/711,234	Filing Date 12/11/2012	☐ To be Mailed
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ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO**APPLICATION AS FILED – PART I**

(Column 1)

(Column 2)

FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

(Column 1)

(Column 2)

(Column 3)

AMENDMENT	10/16/2013	CLAIMS REMAINING AFTER AMENDMENT	Minus	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X \$80 =	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X \$420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
TOTAL ADD'L FEE						0	

(Column 1)

(Column 2)

(Column 3)

AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	Minus	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =
	☐ Application Size Fee (37 CFR 1.16(s))					
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					
TOTAL ADD'L 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.

LIE
/Davina Butler/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
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13/711,234

12/11/2012

KEVIN THOMAS CHRISTENSEN

0837RF-H793-C

1159

38441 7590 07/17/2013
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

EXAMINER

NGUYEN, TAN QUANG

ART UNIT

PAPER NUMBER

3661

NOTIFICATION DATE

DELIVERY MODE

07/17/2013

ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

JIM@WALTONPLLC.COM

Office Action Summary	Application No. 13/711,234	Applicant(s) CHRISTENSEN ET AL.	
	Examiner TAN Q. NGUYEN	Art Unit 3661	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 11 December 2012.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.
- 2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
- 3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
- 4) ☐ Since this application is 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.

Disposition of Claims

- 5) ☒ Claim(s) 1-20 is/are pending in the application.
5a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 6) ☐ Claim(s) _____ is/are allowed.
- 7) ☒ Claim(s) 1-20 is/are rejected.
- 8) ☐ Claim(s) _____ is/are objected to.
- 9) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

- 10) ☐ The specification is objected to by the Examiner.
- 11) ☒ The drawing(s) filed on 11 December 2012 is/are: a) ☒ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

- a) ☐ All b) ☐ Some c) ☐ None of the:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Interim copies:

- a) ☐ All b) ☐ Some c) ☐ None of the: Interim copies of the priority documents have been received.

Attachment(s)

- | | |
|---|---|
| 1) ☒ Notice of References Cited (PTO-892) | 3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____ |
| 2) ☒ Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date <u>12/11/2012</u> | 4) ☐ Other: _____ |

DETAIL ACTION

Notice to Applicant(s)

1. This application has been examined. Claims 1-20 are pending.
2. The prior art submitted on December 11, 2012 has been considered.

Claim Rejections - 35 USC § 102

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. § 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

4. Claims 1-20 are rejected under 35 U.S.C. 102(e) as being anticipated by Piasecki et al. (2010/0324758).
5. As per claim 1, Piasecki et al. disclose the claimed invention which includes at least a lateral control architecture configured to control lateral motion of the aircraft (see at least figure 5 item 74), and longitudinal control architecture configured to control longitudinal motion of the aircraft (see at least figure 5, item 72), wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to

control yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface (see at least figures 5-7, 10, 11 and the related text).

6. As per claims 2-10, the limitations of these claims are shown in at least figures 5-11 and the related text.

7. Claims 11-20 are method claims corresponding to apparatus claims 1-10.

Therefore, claims 11-20 are rejected for the same rationales set forth for claims 1-10.

Conclusion

8. All claims are rejected.

9. The following references are cited as being of general interest: Durno (4,027,999), Shue et al. (2008/0097658) and Cherepinsky et al. (2008/0234881).

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to examiner Tan Q. Nguyen, whose telephone number is (571) 272-6966. The examiner can normally be reached on Monday-Thursday from 6:30 AM-5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black, can be reached on (571) 272-6956.

Any response to this action should be mailed to:

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

or faxed to the Official Fax Center: (571) 273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Application/Control Number: 13/711,234
Art Unit: 3661

Page 4

July 12, 2013

/TAN QUANG NGUYEN/
Primary Examiner
Art Unit 3661

Notice of References Cited	Application/Control No. 13/711,234		Applicant(s)/Patent Under Reexamination CHRISTENSEN ET AL.	
	Examiner TAN Q. NGUYEN		Art Unit 3661	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-4,027,999	06-1977	Durno, Ronald Arthur	416/40
*	B	US-2008/0097658	04-2008	Shue et al.	701/008
*	C	US-2008/0234881	09-2008	Cherepinsky et al.	701/7
*	D	US-2010/0324758	12-2010	Piasecki et al.	701/3
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L4	1	"8332082".PN.	US-PGPUB; USPAT	OR	ON	2013/07/11 20:07
L5	5	(US-20080234881-\$ or US-20030191561-\$ or US-20080097658-\$).did. or (US-8473124-\$ or US-4027999-\$).did.	US-PGPUB; USPAT	OR	ON	2013/07/11 20:08
L6	5	5 AND DIRECTION\$3	US-PGPUB; USPAT	OR	ON	2013/07/11 20:09
L7	53024	longitudinal\$3 and lateral\$3 and directional\$3	US-PGPUB; USPAT	OR	ON	2013/07/11 20:10
L8	5	6 and 7	US-PGPUB; USPAT	OR	ON	2013/07/11 20:10
L9	1031	7 and helicopt\$8	US-PGPUB; USPAT	OR	ON	2013/07/11 20:11
L10	580	9 and head\$4	US-PGPUB; USPAT	OR	ON	2013/07/11 20:11
L11	289	10 and yaw\$4	US-PGPUB; USPAT	OR	ON	2013/07/11 20:11
L12	265	11 and pitch\$3 and roll\$4	US-PGPUB; USPAT	OR	ON	2013/07/11 20:12
L13	81	12 and hover\$4	US-PGPUB; USPAT	OR	ON	2013/07/11 20:12
L14	9	("3083935" "3138349" "4905932" "6270038" "6592071" "7438259" "7908044").PN. OR ("8463465").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2013/07/11 20:17
S1	100	("3554451" "3555194" "3557734" "3557810" "3557814" "3561377" "3561410" "3562410" "3562435" "3562507" "3562581" "3562585" "3564204" "3564274" "3564291" "3564298" "3566026" "3566029" "3566802" "3566919" "3570755" "3575085" "3577035" "3583374" "3589254" "3589559" "3589578" "3589596" "3590156" "3607549" "3621216" "3621387" "3622698" "3624612" "3625604" "3650491" "3670814" "3690361" "3702998" "3773029" "3776604" "3795792" "3818613" "3822060" "3822111" "3838670" "4059157" "4085334" "4213331" "4293950" "4349883" "4509854" "4611842" "4970537" "3554114" "3554182" "3554249" "3554357" "3554439" "3554450"	US-PGPUB; USPAT	OR	ON	2013/07/01 09:20

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S2	1490	grm ground\$3 near3 referenc\$4 near3 maneuver\$4	US- PGPUB; USPAT	OR	ON	2013/07/01 09:38
S3	266	crab\$4 near3 ang\$6	US- PGPUB; USPAT	OR	ON	2013/07/01 09:38
S4	3	S2 and S3	US- PGPUB; USPAT	OR	ON	2013/07/01 09:39
S5	4	("20030191561" "20060186261" "20080234881" "20100308178").PN. OR ("8332082").URPN.	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/01 09:40
S6	3	S3 and pitch\$4 and roll\$4 and longitud\$6 and latitud\$6 and yaw\$4	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/01 09:43
S7	0	S1 and S2	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/01 09:43
S8	35466	helicop\$5 rotar\$6 near3 wing\$3	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/01 09:44
S9	319	S8 and pitch\$4 and roll\$4 and longitud\$6 and latitud\$6 and yaw\$4	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/01 09:44
S10	318	S9 and (direction\$6 orient\$9 head\$4)	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/01 09:45
S11	2	("20030191561" "20080234881").PN.	US- PGPUB; USPAT	OR	ON	2013/07/10 11:02
S12	100	("3554451" "3555194" "3557734" "3557810" "3557814" "3561377" "3561410" "3562410" "3562435" "3562507" "3562581" "3562585" "3564204" "3564274" "3564291" "3564298" "3566026" "3566029" "3566802" "3566919" "3570755" "3575085" "3577035" "3583374" "3589254" "3589559" "3589578" "3589596" "3590156" "3607549" "3621216" "3621387" "3622698" "3624612" "3625604" "3650491" "3670814" "3690361" "3702998" "3773029" "3776604" "3795792" "3818613" "3822060" "3822111" "3838670" "4059157" "4085334" "4213331" "4293950" "4349883" "4509854"	US- PGPUB; USPAT	OR	ON	2013/07/10 11:10

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S14	50	S13 and yaw\$9	US- PGPUB; USPAT	OR	ON	2013/07/10 12:57
S15	6	("20030094001" "20050004723" "5796922" "6089507" "6539290" "7277764").PN. OR ("8473124").URPN.	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/10 13:03
S16	4	("20030191561" "20060186261" "20080234881" "20100308178").PN. OR ("8332082").URPN.	US- PGPUB; USPAT; USOCR	OR	ON	2013/07/10 13:05
S17	3	("20090171545" "20070078042" "6464610").pn.	US- PGPUB; USPAT	OR	ON	2013/07/10 14:31

7/ 11/ 2013 9:33:16 PM
C:\ Users\ tnguyen2\ Documents\ EAST\ Workspaces\ 13-711234 Control helicopter using
long and lateral control.wsp

Search Notes

Application/Control No.

13/711,234

Examiner

TAN Q. NGUYEN

Applicant(s)/Patent under
Reexamination

CHRISTENSEN ET AL.

Art Unit

3661

SEARCHED

Class	Subclass	Date	Examiner
701	3,4,7 14,301	7/2/2013	TN
244	180,181	7/2/2013	TN
340	979	7/2/2013	TN

INTERFERENCE SEARCHED

Class	Subclass	Date	Examiner

**SEARCH NOTES
(INCLUDING SEARCH STRATEGY)**

	DATE	EXMR
PLUS SEARCH	6/28/2013	TN
EAST SEARCH	7/1/2013	TN

12/11/2012

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (07-09)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		13/711,234	
	Filing Date		12/11/2012	
	First Named Inventor	KEVIN T. CHRISTENSEN		
	Art Unit			
	Examiner Name			
	Attorney Docket Number	0837RF-H793-C		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/TN/	1	20080234881	A1	2008-09-25	Cherepinsky, Igor	
/TN/	2	20030191561	A1	2003-10-09	Vos, David	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² i	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T ⁵
/TN/	1	2007018572	WO	A2	2007-02-15	Shue, Shyhyng Jack		☐

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS								
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/Tan Q. Nguyen/

07/01/2013

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number		
Filing Date		
First Named Inventor	KEVIN T. CHRISTENSEN	
Art Unit		
Examiner Name		
Attorney Docket Number	0837RF-H793-C	

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
/TN/	1	International Search Report and the Written Opinion of the International Searching Authority mailed by ISA/USA, U.S. Patent and Trademark Office on 26 August 2011 for corresponding International Patent Application No. PCT/US2011/030498, 7 pages.	☐
/TN/	2	Notice of Allowance dated 2012-08-08 from counterpart US App. No. 13/391,522	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Tan Q. Nguyen/	Date Considered	07/01/2013
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	
First Named Inventor	KEVIN T. CHRISTENSEN
Art Unit	
Examiner Name	
Attorney Docket Number	0837RF-H793-C

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

- ☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

- ☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

- ☐ See attached certification statement.
- ☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.
- ☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/jamesewaltonpat/	Date (YYYY-MM-DD)	2012-12-11
Name/Print	James E. Walton	Registration Number	47,245

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Index of Claims



Application/Control No.

13/711,234

Examiner

TAN Q. NGUYEN

Applicant(s)/Patent under Reexamination

CHRISTENSEN ET AL.

Art Unit

3661

✓	Rejected
=	Allowed

—	(Through numeral) Cancelled
÷	Restricted

N	Non-Elected
I	Interference

A	Appeal
O	Objected

Claim		Date									
Final	Original	7/11/13									
	1	✓									
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PLUS Search Results for S/N 13711234, Searched Fri Jun 28 14:50:29 EDT 2013

The Patent Linguistics Utility System (PLUS) is a USPTO automated search system for U.S. Patents from 1971 to the present PLUS is a query-by-example search system which produces a list of patents that are most closely related linguistically to the application searched. This search was prepared by the staff of the Scientific and Technical Information Center, SIRA.

3554451 99	4293950 99	3560654 58
3555194 99	4349883 99	3560683 58
3557734 99	4509854 99	
3557810 99	4611842 99	
3557814 99	4970537 99	
3561377 99	3554114 58	
3561410 99	3554182 58	
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3822111 99	3559831 58	
3838670 99	3559918 58	
4059157 99	3559920 58	
4085334 99	3559923 58	
4213331 99	3559972 58	

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 13/711,234				
APPLICATION AS FILED - PART I										
(Column 1)		(Column 2)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY				
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)			
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280			
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	600			
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720			
TOTAL CLAIMS (37 CFR 1.16(j))	20	minus 20 = *			OR	x 80 =	0.00			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2	minus 3 = *				x 420 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1600			
APPLICATION AS AMENDED - PART II										
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	OR	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	OR	x	=
	Application Size Fee (37 CFR 1.16(s))							OR		
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	OR	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	OR	x	=
	Application Size Fee (37 CFR 1.16(s))							OR		
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L 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 found in the appropriate box in column 1.										



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
13/711,234	12/11/2012		1400	0837RF-H793-C	20	2

CONFIRMATION NO. 1159

UPDATED FILING RECEIPT



38441
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

Date Mailed: 06/18/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

KEVIN THOMAS CHRISTENSEN, Plano, TX;
SHYHPYNG JACK SHUE, Grapevine, TX;
TROY SHELDON CAUDILL, Burleson, TX;

Applicant(s)

BELL HELICOPTER TEXTRON INC., Fort Worth, TX

Assignment For Published Patent Application

BELL HELICOPTER TEXTRON INC., Fort Worth, TX

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/391,522 02/21/2012 PAT 8332082
which is a 371 of PCT/US11/30498 03/30/2011

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Projected Publication Date: To Be Determined - pending completion of Security Review

Non-Publication Request: No

Early Publication Request: No

Title

FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Preliminary Class**Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:****PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: 13/711,234

Filed: 11 DECEMBER 2012

For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

§ Examiner: TO BE ASSIGNED

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Art Unit: TO BE ASSIGNED

Confirmation No. 1159

**RESPONSE TO NOTICE TO FILE MISSING
PARTS OF NONPROVISIONAL APPLICATION**

Filed via EFS-Web

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Sir:

This Response is being filed in response to the Notice to File Missing Parts of the Nonprovisional Application dated 9 April 2013, which provides for a two-month response period ending 9 June 2013.

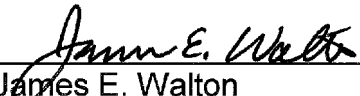
CERTIFICATE OF TRANSMISSION UNDER 37 C.F.R. § 1.8(a)(1)(i)(C)
Date of Transmission: <u>6/7/13</u>
I hereby certify that this correspondence is being transmitted to the U.S. Patent and Trademark Office (USPTO) via the USPTO electronic filing system (EFS-Web) on the date shown above.
By: <u>James E. Walton</u> James E. Walton

The Notice indicates that payment of the surcharge for the Oath or Declaration is required. The Applicants hereby make payment via EFS-Web by designated credit card.

This Response is being filed via the U.S. Patent and Trademark Office's EFS-Web electronic filing system. The surcharge is being paid via a designated credit card. No other fees are deemed to be necessary; however, the undersigned hereby authorizes the Commissioner to charge any fees which may be required, or credit any overpayments, to **Deposit Account No. 502806**.

Respectfully submitted,

6/7/13
Date


James E. Walton
Reg. No. 47,245
Law Offices of James E. Walton, P.L.L.C.
1169 N. Burleson Blvd., Suite 107-328
Burleson, Texas 76028
(817) 447-9955 (Voice)
(817) 447-9954 (Facsimile)
jim@waltonpllc.com

CUSTOMER NO. 38441

ATTORNEY FOR APPLICANTS

Electronic Patent Application Fee Transmittal

Application Number:	13711234			
Filing Date:	11-Dec-2012			
Title of Invention:	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS			
First Named Inventor/Applicant Name:	KEVIN THOMAS CHRISTENSEN			
Filer:	James Edward Walton			
Attorney Docket Number:	0837RF-H793-C			
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Late Filing Fee for Oath or Declaration	1051	1	140	140
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				140

Electronic Acknowledgement Receipt

EFS ID:	15980716
Application Number:	13711234
International Application Number:	
Confirmation Number:	1159
Title of Invention:	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS
First Named Inventor/Applicant Name:	KEVIN THOMAS CHRISTENSEN
Customer Number:	38441
Filer:	James Edward Walton
Filer Authorized By:	
Attorney Docket Number:	0837RF-H793-C
Receipt Date:	07-JUN-2013
Filing Date:	11-DEC-2012
Time Stamp:	14:47:17
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Electronic Funds Transfer
Payment was successfully received in RAM	\$ 140
RAM confirmation Number	1150
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
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1		Response20130607.pdf	171308 7915b4c01d566fc42e9da37f757622a468da8ed2	yes	4
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Miscellaneous Incoming Letter		1	2	
	Applicant Response to Pre-Exam Formalities Notice		3	4	
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30126 dc18d167c213d6ce3f1d57e217129317fe00ea8e	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			201434		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: 13/711,234

Filed: 11 DECEMBER 2012

For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

§ Examiner: TO BE ASSIGNED

§ Art Unit: TO BE ASSIGNED

§ Confirmation No. 1159

TRANSMITTAL

Filed via EFS-Web

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Sir:

Please file the following enclosed documents in the subject application:

1. This Transmittal with Certificate of Transmission; and
2. Response to Notice to File Missing Parts of Nonprovisional Application

CERTIFICATE OF TRANSMISSION UNDER 37 C.F.R. § 1.8(a)(1)(i)(C)

Date of Transmission: 6/7/13

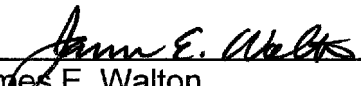
I hereby certify that this correspondence is being transmitted to the U.S. Patent and Trademark Office (USPTO) via the USPTO electronic filing system (EFS-Web) on the date shown above.

By: James E. Walton
James E. Walton

The above-listed documents are being filed via the U.S. Patent and Trademark Office's EFS-Web electronic Filing System. The filing fee is being paid via a designated credit card. No other fees are deemed to be necessary; however, the undersigned hereby authorizes the Commissioner to charge any fees which may be required, or credit any overpayments, to **Deposit Account No. 502806**.

Respectfully submitted,

6/7/13
Date


James E. Walton
Reg. No. 47,245
Law Offices of James E. Walton, P.L.L.C.
1169 N. Burleson Blvd., Suite 107-328
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CUSTOMER NO. 38441

ATTORNEY FOR APPLICANTS



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
13/711,234	12/11/2012		1260	0837RF-H793-C	20	2

CONFIRMATION NO. 1159

38441
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

FILING RECEIPT



Date Mailed: 04/09/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

KEVIN THOMAS CHRISTENSEN, Plano, TX;
SHYHPYNG JACK SHUE, Grapevine, TX;
TROY SHELDON CAUDILL, Burleson, TX;

Applicant(s)

BELL HELICOPTER TEXTRON INC., Fort Worth, TX

Assignment For Published Patent Application

BELL HELICOPTER TEXTRON INC., Fort Worth, TX

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/391,522 02/21/2012 PAT 8332082
which is a 371 of PCT/US11/30498 03/30/2011

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Projected Publication Date: To Be Determined - pending completion of Security Review

Non-Publication Request: No

Early Publication Request: No

Title

FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Preliminary Class**Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:****PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 13/711,234				
APPLICATION AS FILED - PART I										
(Column 1)		(Column 2)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY				
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)			
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280			
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	600			
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720			
TOTAL CLAIMS (37 CFR 1.16(j))	20	minus 20 = *			OR	x 80 =	0.00			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2	minus 3 = *				x 420 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL		TOTAL	1600			
APPLICATION AS AMENDED - PART II										
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	OR	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	OR	x	=
	Application Size Fee (37 CFR 1.16(s))							OR		
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	OR	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	OR	x	=
	Application Size Fee (37 CFR 1.16(s))							OR		
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L 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 found in the appropriate box in column 1.										



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United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/711,234	12/11/2012	KEVIN THOMAS CHRISTENSEN	0837RF-H793-C

38441
LAW OFFICES OF JAMES E. WALTON, PLLC
1169 N. BURLESON BLVD.
SUITE 107-328
BURLESON, TX 76028

CONFIRMATION NO. 1159
FORMALITIES LETTER



Date Mailed: 04/09/2013

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing.

Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- A surcharge (for late submission of the basic filing fee, search fee, examination fee or inventor's oath or declaration) as set forth in 37 CFR 1.16(f) of \$ **140** for an undiscounted entity, must be submitted.

SUMMARY OF FEES DUE:

Total fee(s) required within **TWO MONTHS** from the date of this Notice is \$ **140** for an undiscounted entity

- \$ **140** Surcharge.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

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Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

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<https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html>

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at <http://www.uspto.gov/ebc>.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/bmnguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of
Invention

Flight Control Laws for Constant Vector Flat Turns

As the below named inventor, I hereby declare that:

This declaration
is directed to:



The attached application, or



United States application or PCT international application number 13/711,234

filed on 11 December 2012

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

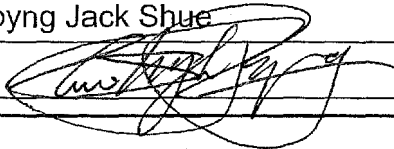
WARNING:

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LEGAL NAME OF INVENTOR

Inventor: Shyhyng Jack Shue

Date (Optional): Jan. 14, 2013

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	Flight Control Laws for Constant Vector Flat Turns
---------------------------	---

As the below named inventor, I hereby declare that:

This declaration is directed to: ☐ The attached application, or ☒ United States application or PCT international application number 13/711,234 filed on 11 December 2012

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

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LEGAL NAME OF INVENTOR

Inventor: Kevin Thomas Christensen Date (Optional): 1/9/13

Signature: *Kevin T Christensen*

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	14857884
Application Number:	13711234
International Application Number:	
Confirmation Number:	1159
Title of Invention:	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS
First Named Inventor/Applicant Name:	KEVIN THOMAS CHRISTENSEN
Customer Number:	38441
Filer:	James Edward Walton
Filer Authorized By:	
Attorney Docket Number:	0837RF-H793-C
Receipt Date:	01-FEB-2013
Filing Date:	
Time Stamp:	17:19:45
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Declarations20130201.pdf	433201 676d8acf88bd5c0695b459cc68ecfb5a4a166b9	yes	5

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Miscellaneous Incoming Letter	1	2
	Oath or Declaration filed	3	3
	Oath or Declaration filed	4	4
	Oath or Declaration filed	5	5

Warnings:

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: 13/711,234

Filed: 11 DECEMBER 2012

For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

§ Examiner: TO BE ASSIGNED

§

§

§

§

§

§

§

§

§

Art Unit: TO BE ASSIGNED

Confirmation No. 1159

TRANSMITTAL

Filed via EFS-WEB

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Sir:

Please file the following enclosed documents in the subject application:

1. This Transmittal with Certificate of Transmission; and
2. Declaration executed by the inventors, form PTO/AIA/01a.

CERTIFICATE OF TRANSMISSION UNDER 37 C.F.R. § 1.8(a)(1)(i)(C)

Date of Transmission: 2/1/13

I hereby certify that this correspondence is being transmitted to the U.S. Patent and Trademark Office (USPTO) via the USPTO electronic filing system (EFS-Web) on the date shown above.

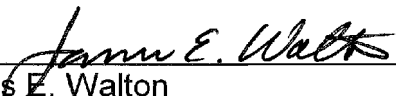
By:

James E. Walton
James E. Walton

Please file the above-listed documents in the subject application. The documents are being filed via the U.S. Patent and Trademark Office's EFS-Web electronic filing system. No fees are deemed to be necessary; however, the undersigned hereby authorizes the Commissioner to charge any additional fees that may be required, or credit any overpayments, to **Deposit Account No. 502806**.

Respectfully submitted,

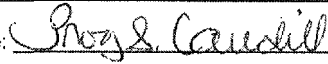
Date 2/1/13


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(817) 447-9954 (Facsimile)
jim@waltonpllc.com (Email)

CUSTOMER NO. 38441

ATTORNEY FOR APPLICANTS

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention	Flight Control Laws for Constant Vector Flat Turns
As the below named inventor, I hereby declare that: This declaration is directed to: ☐ The attached application, or ☒ United States application or PCT international application number <u>13/711,234</u> filed on <u>11 December 2012</u> The above-identified application was made or authorized to be made by me. I believe that I am the original inventor or an original joint inventor of a claimed invention in the application. I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both. WARNING: Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.	
LEGAL NAME OF INVENTOR Inventor: <u>Troy Sheldon Caudill</u> Date (Optional) : _____ Signature: <u></u>	
Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.	

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	Flight Control Laws for Constant Vector Flat Turns
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As the below named inventor, I hereby declare that:

This declaration is directed to: ☒ The attached application, or

☐ United States application or PCT international application number _____

filed on _____.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

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LEGAL NAME OF INVENTOR

Inventor: Kevin Thomas Christensen Date (Optional) : _____

Signature: _____

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**Title of
Invention**

Flight Control Laws for Constant Vector Flat Turns

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LEGAL NAME OF INVENTOR

Inventor: Shyhyng Jack Shue Date (Optional) : _____

Signature: _____

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: TO BE ASSIGNED

Filed: HEREWITH

For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

§ Examiner: TO BE ASSIGNED

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Art Unit: TO BE ASSIGNED

Confirmation No.

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Filed herewith is a Form PTO/SB/08a listing references that may be material to the patentability of the invention disclosed and claimed in the subject application. This submission is made pursuant to 37 C.F.R. § 1.56 and is being filed under 37 C.F.R. § 1.97(b)(1) within three months of the filing date of a national application.

CERTIFICATE OF TRANSMISSION UNDER 37 C.F.R. § 1.8(a)(1)(i)(C)
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I hereby certify that this correspondence is being transmitted to the U.S. Patent and Trademark Office (USPTO) via the USPTO electronic filing system (EFS-Web) on the date shown above.
By: <u>James E. Walton</u> James E. Walton

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Respectfully submitted,

12/6/12
Date


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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		
	Filing Date		
	First Named Inventor	KEVIN T. CHRISTENSEN	
	Art Unit		
	Examiner Name		
	Attorney Docket Number	0837RF-H793-C	

U.S.PATENTS						
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	1	20080234881	A1	2008-09-25	Cherepinsky, Igor	
	2	20030191561	A1	2003-10-09	Vos, David	

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	1	2007018572	WO	A2	2007-02-15	Shue, Shyhpyng Jack		☐

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Application Number		
Filing Date		
First Named Inventor	KEVIN T. CHRISTENSEN	
Art Unit		
Examiner Name		
Attorney Docket Number	0837RF-H793-C	

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	1	International Search Report and the Written Opinion of the International Searching Authority mailed by ISA/USA, U.S. Patent and Trademark Office on 26 August 2011 for corresponding International Patent Application No. PCT/US2011/030498, 7 pages.	☐
	2	Notice of Allowance dated 2012-08-08 from counterpart US App. No. 13/391,522	☐

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(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	
First Named Inventor	KEVIN T. CHRISTENSEN
Art Unit	
Examiner Name	
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CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

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☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

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A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/jamesewaltonpat/	Date (YYYY-MM-DD)	2012-12-11
Name/Print	James E. Walton	Registration Number	47,245

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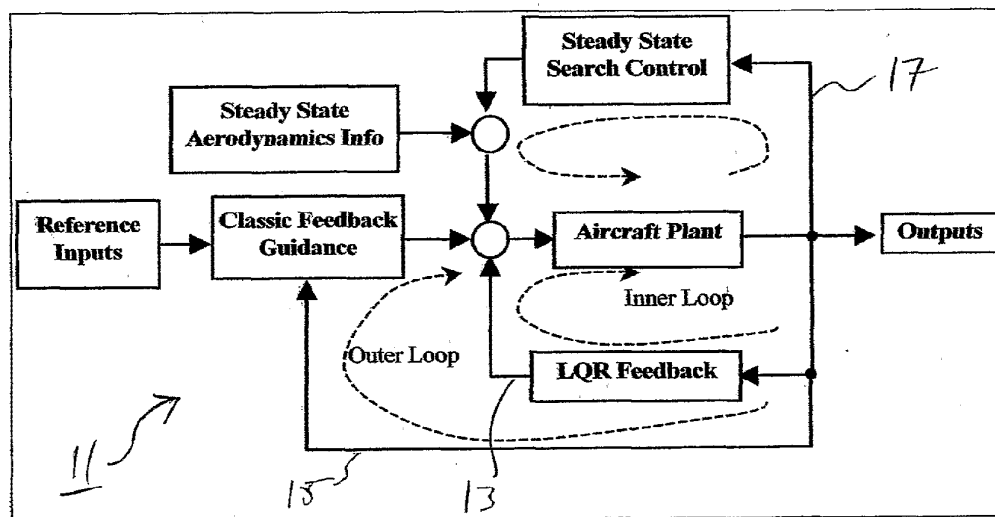
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(54) Title: FLIGHT CONTROL SYSTEM HAVING A THREE CONTROL LOOP DESIGN



(57) Abstract: A flight control system is configured for controlling the flight of an aircraft utilizing a three control loop design to robustly increase system performance. An inner loop comprises an improved linear quadratic regulator (LQR) search method, and an outer loop comprises a classic feedback summary gain design. A third loop comprises a steady state trim search method.

FLIGHT CONTROL SYSTEM HAVING A THREE CONTROL LOOP DESIGN

Technical Field

5 The present invention relates generally to the field of flight control systems for manned and unmanned aircraft and specifically to systems configured for robustly improving flight performance.

Description of the Prior Art

10 Control of an unstable aircraft flight system, such as a helicopter, has proven to be very challenging using classic feedback control laws. One method for controlling a helicopter employs purely classic feedback control laws, and this method requires a significant amount of flight testing to adjust individual gains to ensure the system's stability. In addition, flight quality depends upon adjustment of these gains and the natural design of the helicopter. Improvement of the system performances and maneuvers are limited, and robustness of the flight control system
15 may not be considered in this method.

Another method is classic feedback with optimal gain search. For this method, the individual optimal search algorithm needs to be manually computed to be added into the system. When the flight performance is not as desired, changing these gains takes time, which may delay flight testing and increase engineering
20 hours. The improved performance for this method is also limited, and robustness of the system is not guaranteed in this method.

It should be noted that by stabilizing the whole system, the designer needs to introduce many error corrections and gain-scheduling techniques. However, while trying to stabilize the system and also guide the aircraft in all maneuvers, the classic
25 feedback control laws may need to fine tune all gains so that the control laws can complete their objectives. This method does not lead to the development of sufficiently robust control laws.

Summary of the Invention

There is a need for a flight control system that provides for an improved flight control system having a three control loop design.

Therefore, it is an object of the present invention to provide a flight control system that provides for an improved flight control system having a three control loop design.

A flight control system is configured for controlling the flight of an aircraft utilizing a three control loop design to robustly increase system performance. An inner loop comprises an improved linear quadratic regulator (LQR) search method, and an outer loop comprises a classic feedback summary gain design. A third loop comprises a steady state trim search method.

The present invention includes significant benefits and advantages, including: (1) increasing handling qualities and performance for piloted aircrafts; (2) increasing robustness for unmanned aircrafts; (3) reducing flight test time; (4) reducing flight control law development time; (5) providing for easily applied intelligent portion for unmanned control; (6) providing for the system to be easily understood and implemented by engineers; and (7) using all advantages from classic feedback and modern control methods and eliminating their disadvantages.

Brief Description of the Drawings

For a more complete understanding of the present invention, including its features and advantages, reference is now made to the detailed description of the invention taken in conjunction with the accompanying drawings in which like numerals identify like parts, and in which:

FIG. 1 is a schematic view of a flight control system according to the present invention;

FIG. 2 is a schematic view showing block diagrams of portions of the system of Figure 1;

FIG. 3 is a graph showing aircraft states plotted against airspeed for a system using a LQR method;

FIG. 4 is a graph showing aircraft states plotted against airspeed for a system according to the present invention;

5 FIG. 5 is a flow chart showing the LQR method according to the present invention;

FIG. 6 is a graph showing the location of closed loop eigenvalues for longitudinal motions for different airspeeds;

10 FIG. 7 is a schematic view of the pitching angle steady state trim control law according to the present invention;

FIG. 8 is a graph showing aircraft states plotted against airspeed for a system according to the present invention, the graph showing the enlarged stability from use of the trim search method;

FIG. 9 is a schematic view of a portion of the system of Figure 1;

15 FIG. 10 is a schematic view of a portion of the system of Figure 1;

FIG. 11 is a schematic view of a portion of the system of Figure 1;

FIG. 12 is a plot showing an example of a square flight path used in simulations using the system according to the present invention; and

20 FIGS. 13 through 16 are plots showing the simulated flight of an aircraft using the system according to the present invention and following the flight path of Figure 12.

Description of the Preferred Embodiment

25 The present invention is directed to a three control loop flight control system configured for automatically controlling the flight of an aircraft. One purpose of the present invention is to make an open-loop unstable aircraft system stable by: (1) making the system stable first; (2) allowing the aircraft to be capably guided to any

waypoint with any required airspeed; and (3) allowing the aircraft to save control effort for possible maneuvers.

5 The three control loop design of the present invention will robustly enlarge the stability of the aircraft control laws. Instead of using classic feedback control law, the present invention enhances the system by: (1) leaving the strongest portion of classic feedback control system; and (2) introducing two other control laws to handle the natural weakness of classic feedback control law. The present invention saves flight test periods and shortens the time required to design control laws. Use of the three control loops has been as capable of making unstable aircraft to be not only
10 stabilized but also guided and navigated, whereas the pure classic feedback control laws cannot even stabilize the system.

The present invention applies three control techniques to stabilize, guide, and navigate the aircraft at the same time. All control techniques are pre-programmed. In this way, the present invention reduces gain search and adjustment efforts from development to flight test. In addition, the invention ensures the aircraft will have the
15 best performance and handling quality by satisfying eigenvalue and damping ratio criterion, as well as eigenvalue and eigenvector bound per fast and slow frequency. The maneuverable relationship between lateral, longitudinal, and control power are extremely improved. The control effort for standard simple maneuvers is essentially
20 reduced through the use of a steady state trim search control loop.

Aircraft control, guidance, and navigation are implemented by a group of linear models, which are computed from aerodynamic analysis. The aerodynamic analysis input is generated from wind tunnel data with computational fluid dynamics information. The linear models generated have been shown to provide the closest
25 agreement between the flight test and real time simulation. Therefore, as the design concept has been shown to be fully controllable with very good maneuvers in the simulation, it can be employed to guide the helicopter to anywhere at any speed and at any altitude. In order to improve flight maneuvers and performance and increase robustness of the system from technical experience, classic flight control laws are re-
30 designed and divided into three portions.

Referring to the figures, Figure 1 is a schematic view of one embodiment of the flight control system according to the invention. System 11 comprises three loops: inner loop 13; outer loop 15; and steady state trim loop 17.

5 Inner loop 13 is introduced from optimal modern control concept with best phase margin and gain margin concept to achieve stabilization of the system. To accomplish the best phase margin and gain margin design, an algorithm based on eigenvalue, eigenvector, and damping ratio from time domain approach is employed.

10 Outer loop 15 is inherited from the classic feedback control laws. This portion is improved through a summary gain design, wherein instead of adjusting individual gains, the summary gain design is employed to shorten gain selection. The main purpose of this outer loop is to guide the helicopter to desired yaw angle, roll angle, airspeed, and altitude.

15 Steady state trim loop 17 is used to automatically search for the best trim conditions at any flight conditions in order to save control effort for other flight maneuvers. Steady state trim search control law design is employed in steady state trim loop 17 to find the best flight condition under any one of the following objectives:
(1) altitude rate, $\dot{h}$, to be close to zero for level flight or a constant value for steady state climbing; (2) roll rate, p , to be close to zero for level flight or a constant value for level turn in higher airspeed; and (3) yaw rate, r , to be close to zero for level
20 flight or a constant value for level turn in lower airspeed. Therefore, the flight control laws will automatically catch the trim flight, such as: steady state level flight; steady state coordinate turn; steady state climbing while airspeed is fixed; and steady state increasing airspeed while altitude is held. By utilizing the present invention, the system will always fly close to its trim condition. When control effort required for
25 steady state trim is minimized, the remaining control authority allows the aircraft to fly more difficult maneuvers.

Definition of Simulation Block Diagrams

Names and explanations of individual block diagram used in the simulation of the system of the invention are shown in Figure 2 and tabulated in Table I below.

Each block diagram may contain more than one control, guidance, or navigation logic element.

TABLE I: Block Diagram definition

No	Block Name	Purpose
1	AircraftSS	Aircraft State Space equation of motion from analysis
2	Sensors_Jack	Aircraft six degree of freedom nonlinear equations of motion.
3	Climb_Formula	Computing the helicopter velocity U from u , v , and w . Use U to generate angle of attack, α , and climb angle, γ , from pitch angle, θ .
4	Actuators	There are four actuator dynamic functions in this diagram. They are Pedal, Lateral, Longitudinal, and Collective actuators. All actuators are with their limiter.
5	Control_Switch	This diagram is used to manually switch several modes. This diagram is like switch panels on a remote cockpit station.
6	Display	This diagram is employed to display all internal state variables used for the simulation.
7	NavSensors	NavSensor is similar to aircraft's Flight Management System (FMS). FMS contains three portions: Flight Plan, VNAV, and Waypoint NAV.
8	RollSCAS	RollSCAS guidance system
9	RollAttd	Roll Attitude Hold function

10	RollHdgHold	Heading Hold while rolling
11	HdgSelect	This block is to compute the heading from desired input so that the helicopter will fly to the desired heading during higher airspeeds.
12	TurnCoord	This block is to maintain steady state turn at airspeeds higher than 45 knots
13	RollOuter	To determine where the roll command feedback is coming from.
14	Feedback_Lat	LQR control feedback for stabilizing lateral control input
15	PitchSCAS	Pitch moment command for guidance purpose
16	PitchATTD	Several gains need to be adjusted correctly so that the PitchATTD will be held. These gains are: Q_gain, T_q_gain, T_gain, T_fdbk_gain, T_counter_Gain, Turn_Coord_q_gain.
17	Speed	Several gains need to be adjusted correctly so that the Speed will be held. These gains are: Spd_Ax_gain, Spd_udot_gain, Spd_TAS_gain, Spd_Counter_Gain, SPD_Sum_Gain, SPD_slew_Gain.
18	AltitudeVS	Several gains need to be adjusted correctly so that the Altitude_VS will be held. These gains are: Alt_q_gain, Alt_T_gain, Alt_Nz_gain, Alt_slew_Gain, Alt_slew_Gain1, Alt_Sum_Gain, Alt_Pitch_VS_Gain, Coll_Cmnd_VS_Gain.
19	AltitudeSel	This block is used to generate Alt_Track and Alt_Capture Boolean command for ensuring

		that Altitude in under tracking within ± 20 feet. These values are determined by two constants in the block.
20	PitchOuter	This block is to determine whether the system pitch moment shall come from Hover or Pitch_VS or Pitch_Long.
21	Feedback_Long	LQR is used to generate the necessary Longitudinal feedback gain to stabilize Long_motion so that the guidance system will focus on its own rule and not on the system stabilization.
22	YawSCAS	This block is used to determine whether the YawSCAS shall get the necessary control calculation from Yaw-Ped (low speed) or from Roll cmdnd (High speed).
23	YawOuter	This block is used to make helicopter turns at low speed. The following gains need to be adjusted correctly: Psi_Ay_gain, Psi_r_gain, Psi_r_sum_gain, Psi_CRS_gain, Psi_R_TF, Psi_Ay_TF,
24	CollOuter	Used to determine if the collective shall provide its control for hover or speed or Alt. There is one gain from Coll_TF, which can be used to adjust the force produced from coll_controller.
25	Hover	This block is used to determine x, y, and z distance for hover condition.
26	ModeLogic	Used to determine which mode shall be on and off with all aircraft conditions.

27	Navigation	This block is used to make helicopter turn.
28	Interactive_Cont	Used like remote control stick to make helicopter to go to the desire heading, airspeed, and altitude. Turn on/off manual switches to make helicopter to go the desired values.
29	Delta_H_Function	Used to compute the difference from u, v, and w for future function.
30	Theta_Guidance	Used to ensure Theta will go to the steady state value by LQR method.
31	Ay_Guidance	Used to ensure Theta will go to the steady state value by LQR method.
32	Phi_Guidance	Used to ensure Theta will go to the steady state value by LQR method.
33	Psi_Guidance	Used to ensure Theta will go to the steady state value by LQR method.
34	w_Guidance	Used to ensure Theta will go to the steady state value by LQR method.
35	ss_Selection_Fdbk	Uses gain schedule theory to provide the steady state trim values for all guidance blocks. Because of this design, the system will easily reach its steady state values while keeping the control effort to minimum.

Block diagrams (1) - (7) model basic aircraft systems, which are well known in the art.

Block diagrams (8) – (13), (15) – (20), and (22) – (24) are designed based on classic feedback laws. These diagrams are to work as helicopter guidance systems.

Block diagrams (14) and (21) are developed from Linear Quadratic Regulator (LQR). While developing LQR control laws for inner loop system, decoupling of longitudinal and lateral functions is applied. In addition, separation of control laws with gain-scheduling control per true airspeed for LQR to actuators is also implemented.

Block diagrams of (6) and (25) - (27) are the intelligent portion of the system with avionics flight management system (FMS) for waypoint selection and navigation.

Block diagram (28) is worked as a remote flight control panel. It will allow remote pilots to input flight information, and the combination of this diagram with Display diagram (6) will form a remote ground station display system.

Block diagrams of (29) – (35) are for Steady State Trim Search Loop (Figure 1). These diagrams are generated based on LQR model matching technology to search for the best steady state trim values in any flight conditions.

Inner Loop Stability Analysis and Control

Open loop eigenvalues of aircraft are often unstable. In order to avoid repeatedly adjusting all gains to make all open loop systems stable, a LQR technique is employed to achieve this goal quickly. However, there are several techniques also being employed to simplify the process of finding good control gains for the system so that the model can be stable on the bigger nonlinear stable domain. As shown in Figure 3, LQR will allow the nonlinear helicopter system to be stable in, for example, small regions 19, 21, 23 immediately from its open loop unstable system.

In order to enlarge aircraft stability from a small region to a belt type of plane, full model decoupling, separation of control laws, and gain scheduling technique are applied, so that the stability of the system will be expanded. For example, Figure 4 shows expanded stability region 25.

The sequence process and computation methods to expand the stability region are represented by the flow chart depicted in Figure 5. Block 27 represents the linear models derived from aerodynamics analysis and wind tunnel data, and block 29 shows the separation of control laws into flow paths for longitudinal and lateral component. The longitudinal motion input, represented by block 31, passes to longitudinal LQR block 33 and then to gain scheduling block 35. Likewise, the lateral motion input, represented by block 37, passes to lateral LQR block 39 and then to gain scheduling block 41. The outputs from each of these paths are then regrouped in block 43.

Decoupling Full Model

A linear model of aircraft can be obtained from aerodynamics data, and a group of linear models can be developed based on its airspeed. These linear models can be represented as follows:

$$\begin{aligned}\dot{X} &= A_k X + B_k U \\ Y &= C_k X\end{aligned}\quad \text{where } k = 0, 1, 2, \dots, \text{ or } j \quad (1)$$

where X is the state variables, $(u, v, w, \theta, \psi, p, q, r)^T$, U is control vector, $(\delta_{ped}, \delta_{long}, \delta_{lat}, \delta_{coll})^T$, Y is performance output vector, $(X^T, \dot{u}, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, A_x, A_y, N_z)^T$. A_0, A_1, A_2 are the state matrices with $k = 0$ for hover, $k = 1$ for 10 knots and $k = 2$ for 20 knots, respectively. Total model, j , selected for computation depends on the maximum airspeed of aircraft. B_0, B_1, B_2 are the control matrices, and C_0, C_1, C_2 are the performance output matrices. Please note that dimension of (A_0, A_1, A_2) is 8×8 , dimension of (B_0, B_1, B_2) is 8×4 , and dimension of (C_0, C_1, C_2) is 17×8 . Since these matrices are large and contain coupling terms of lateral and longitudinal motions within these matrices, it is difficult to determine the best performance LQR control gains for all at the same time. In order to overcome these issues, the full model in equation (1) is decoupled first. After decoupling lateral and longitudinal equations of motion, equation (1) can be transformed to

Lateral equation of motion:

$$\begin{aligned}\dot{X}^{lat} &= A_k^{lat} X^{lat} + B_k^{lat} U^{lat} \\ Y^{lat} &= C_k^{lat} X^{lat}\end{aligned}\quad \text{where } k = 0, 1, 2, \dots, \text{ or } j \quad (2)$$

Longitudinal equation of motion:

$$\begin{aligned}\dot{X}^{long} &= A_k^{long} X^{long} + B_k^{long} U^{long} \\ Y^{long} &= C_k^{long} X^{long}\end{aligned}\quad \text{where } k = 0, 1, 2, \dots, \text{ or } j \quad (3)$$

where X^{lat} is $(v, \phi, p, r)^T$, X^{long} is $(u, w, \theta, q)^T$, U^{lat} is $(\delta_{ped}, \delta_{lat})^T$, and U^{long} is $(\delta_{long}, \delta_{coll})^T$. A_k^{lat} and A_k^{long} are 4×4 matrices, B_k^{lat} and B_k^{long} are 4×2 matrices, and C_k^{lat} and C_k^{long} are simplified to be 4×4 and 4×4 matrices, respectively. This implies that only state variables are employed to provide LQR full state feedback control laws.

After the full aircraft model (1) is decoupled to lateral (2) and longitudinal (3) motions, the effect of coupling terms between lateral and longitudinal motions can be reduced to minimum, while applying LQR to stabilize the system.

Improved Linear Quadratic Regulator (LQR)

Linear quadratic regulator (LQR), also known as optimal control law, has attracted plenty of attention in the aircraft industry since it was used on the General Dynamics/Lockheed Martin F-16 as its major feedback control system. The objective of LQR state regulation is to drive any initial condition errors to zero, thus it guarantees the stability of the system. To achieve this goal, the lateral and longitudinal control inputs, U^{lat} and U^{long} , generated from (2) and (3), apply state feedback control laws as follows

$$U^{lat} = -K^{lat} X^{lat} \quad (4)$$

$$U^{long} = -K^{long} X^{long} \quad (5)$$

to minimize lateral and longitudinal cost functions or performance indexes of the type

$$\min \left\{ J^{lat} = \frac{1}{2} \int_0^\infty (X^{latT} Q_{lat} X^{lat} + U^{LatT} R_{lat} U^{lat}) dt \right\} \quad (4)$$

$$\min \left\{ J^{long} = \frac{1}{2} \int_0^\infty (X^{long^T} Q_{long} X^{long} + U^{Long^T} R_{long} U^{long}) dt \right\} \quad (5)$$

where state weighting matrices (Q_{lat} and Q_{long}) are symmetric positive semi-definite and control weighting matrices (R_{lat} and R_{long}) are positive definite with matched dimensions for state variables and control inputs.

- 5 It is very important to select a good performance criterion that will provide good stability and time responses for all control gains simultaneously. The following steps are experienced and summarized to find these best performance indexes for aircraft inner loop optimal state feedback/control laws:
 - a) Initially set (Q_{lat} and Q_{long}) to be very small positively diagonal values
 - 10 b) Set (R_{lat} and R_{long}) to be identity matrices
 - c) Adjust (Q_{lat} and Q_{long}) only and leave (R_{lat} and R_{long}) to be identity
 - d) Set the weighting coefficients related to its angular rate or speed states to be a multiple of 10 times its angles or distance states; for example, $q_w = 10 \cdot q_z$ and $q_r = 10 \cdot q_\psi$, where q is local weighting coefficient
 - 15 e) After rules of (d) are set, multiply a constant positive value for weighting matrices to adjust all coefficients at one time
 - f) Check eigenvalues of closed loop and open loop systems and ensure individual eigenvalue shift is not too large
 - g) After all eigenvalues are close to the desired values, fine-tune the individual

20 weighting coefficients to make improve performance

With the above weighting selection rules, the optimal control gain generated from these weighting matrices will make the system stable for individual airspeeds, as shown in Figure 3. Therefore, the optimal state feedback control gains from the weighting matrices (Q_{lat} and Q_{long}) and (R_{lat} and R_{long}) can be determined as

$$K^{lat} = -R_{lat}^{-1} B_{lat}^T P_{lat} \quad (6)$$

$$K^{long} = -R_{long}^{-1} B_{long}^T P_{long} \quad (7)$$

where $(P_{lat}$ and $P_{long})$ are symmetric positive definite and satisfy the following algebraic Riccati equations (ARE)

$$5 \quad A^{latT} P_{lat} + P_{lat} A^{lat} + Q_{lat} - P_{lat} B^{lat} R_{lat}^{-1} B^{latT} P_{lat} = 0 \quad (8)$$

$$A^{longT} P_{long} + P_{long} A^{long} + Q_{long} - P_{long} B^{long} R_{long}^{-1} B^{longT} P_{long} = 0 \quad (9)$$

with the following constraints

i) (A^{lat}, B^{lat}) and (A^{long}, B^{long}) are stabilizable

ii) $(A^{lat}, Q_{lat}^{1/2})$ and $(A^{long}, Q_{long}^{1/2})$ are detectable

10 iii) $(Q_{lat}$ and $Q_{long})$ are symmetric positive semi-definite and $(R_{lat}$ and $R_{long})$ are symmetric positive definite

Note that individual eigenvalues of the linear system from the above process can be shifted to the certain specific region. For example, Figure 6 shows all eigenvalues locations for airspeed on hover, 40 knots, 80 knots and 120 knots for longitudinal motion. This figure clearly shows that eigenvalues of all four different linear models are moved to very close regions 45, 47. Therefore, the guidance system used to direct the aircraft to any altitude, airspeed, and direction will not need to be gain scheduling.

Separation of Feedback Controls

20 In order to save control effort while stabilizing the system, separation of control laws is applied. The first control law is called "inner loop control" which applies LQR to stabilize the open-loop system as described above. After LQR state feedback control inputs for lateral and longitudinal motions are developed, these control inputs are fed back thru Actuator diagram (4). Instead of adding the whole vector by LQR method, the controls are separated per their feedback targets. For

example, (U_1^{lat}, U_2^{lat}) are for yaw and lateral controller, respectively, and (U_1^{long}, U_2^{long}) are for longitudinal and collective controller, respectively. These controllers (U_1^{lat}, U_2^{lat}) and (U_1^{long}, U_2^{long}) are a portion of its total control. Total actuator shown in Actuator diagram (4) not only allows the system control from LQR, but also classic feedback guidance control and the steady state search method. Separation of total individual control can be divided into four or five portions as shown in Table II.

TABLE II: Separation of control

Controller Motion	Control Name	Purpose
Yaw Control	Ulat_Ped	LQR stabilization
	Yaw_Act_Cmnd	Classic guidance system
	Psi_Cmnd_Ped	Steady state trim search for ψ
	Pedal_Trim	Initial trim pedal value
Roll Control	ULat_Lat	LQR stabilization
	Roll_Act_Cmnd	Classic guidance system
	Phi_Cmnd_Ped	Steady state trim search for ϕ
	v_Cmnd_Lat	steady state trim search for v
Longitudinal Control	Lateral_Trim	Initial trim lateral value
	ULong_Long	LQR stabilization
	Pitch_Act_Cmnd	Classic guidance system
	Theta_Cmnd_Long	Steady state trim search for θ
	w_Cmnd_Ped	Steady state trim search for w

	Long_Trim	Initial trim longitudinal value
Collective Control	Ulong_Coll	LQR stabilization
	Coll_Act_Cmnd	Classic guidance system
	Theta_Cmnd_Long	steady state trim search for θ
	z_Cmnd_Long	Steady state trim search for z
	Coll_Trim	Initial trim collective value

With this separation of control inputs, each controller has its own objectives. Aircraft control is simplified and special maneuvers are now possible.

Algorithm of LQR Gain Scheduling Values

5 Stabilization and guidance of fixed wing aircraft or helicopters just using one feedback is difficult at best and may take a significant amount of time to find a proper feedback gain that can control the system within a small region. To avoid searching the right gains per phase margins and gain margin from classic feedback control laws, gain schedule method calculated from LQR is applied to save this effort. It is shown that the feedback gains generated from LQR always provide the best performance because it minimizes an energy cost function. In addition, all eigenvalues will be shifted to the desired region, and the guidance law gain scheduling can be avoided. Plotting various eigenvalues, eigenvectors, and damping ratios with respect to their various airspeeds will allow the designers to find a stable belt region in the global region for the system.

20 In order to complete this kind of task, the system needs to be divided into several segments. In this application, the open loop system is separated into several segments per airspeeds at hover, 10 knots, 20 knots, etc. LQR control gains generated from these airspeeds can be specified per formulations from the Improved LQR discussion above. In order to ensure all gain schedule values of the closed loop eigenvalues generated from these LQR methods will be within the best stable and performance region, eigenvalues, eigenvectors, and damping ratios of all three

LQR closed loop systems are employed to complete this evaluation and investigation. The following algorithm is employed to complete this search:

- a) Obtain LQR feedback for airspeed = 0, 10 and 20 knots, etc.
- b) Compute eigenvalues, eigenvectors and damping ratios of closed loop systems from Step a) for all cases.
- c) Check eigenvalues, and ensure they are all stable.
- d) Check open loop eigenvalues and closed loop eigenvalues, and ensure that the closed loop eigenvalues did not be move too far away from their open loop eigenvalues.
- e) Check eigenvectors, and ensure the directions of all three are the same direction and within a tolerance, Δ . The formulation of this tolerance will be discussed in equation (10) below.
- f) Check all damping ratios, and ensure they are all damping ratios greater than 0.5.
- g) If Steps a) thru f) are satisfied, stop and set these feedbacks as gain schedule values, which will provide the system is not only stable but also has very good performance.
- h) If Steps a) thru f) are not satisfied, adjust LQR weighting matrices until Steps a) thru f) are satisfied.

The eigenvector tolerance, Δ , shown in Step e) is formulated as

$$\Delta_{0 \rightarrow 1} = \|v_0 - v_1\| \leq \kappa \|\lambda_1 - \lambda_2\| \quad (10)$$

where v_0 and v_1 are related individual eigenvectors from airspeed at hover and 10 knots, λ_0 and λ_1 are its eigenvalues, and constant value, κ , depends on fast mode or slow mode of the system. For fast eigenvalues, since absolute eigenvalues of fast mode are much larger than that of the slow mode, κ is set to be $0.2 \|\lambda_f\|$ and κ is set to be $0.5 \|\lambda_s\|$ for the slow mode. With these settings, the changes of

eigenvector and eigenvalue set will be limited within the desired paths and values. Therefore, these eigenvectors and eigenvalues can be used for gain scheduling to keep the aircraft flight within desired performance.

Steady State Trim Search and Control Laws

5 In order to save control effort for the system, the second loop, steady state trim search control laws, is applied.

It is assumed that in the state space nonlinear region, there is a set of steady state values, which will make the system to have

- 10 1) Altitude rate, $\dot{h}$, close to zero for level flight or a constant value for steady state climbing.
- 2) Roll rate, $\dot{p}$, close to zero for level flight or a constant value for level turn in higher airspeed.
- 3) Yaw rate, $\dot{r}$, close to zero for level flight or a constant value for level turn in lower airspeed.

15 The objective of steady state trim search control laws is to find a set of feedback controllers such that the aircraft will follow the steady state trim values to automatically catch the trim flight. For example:

- Steady state level flight
- Steady state coordinated turn
- 20 • Steady state climbing while airspeed is fixed
- Steady state increasing airspeed while altitude is held.

If the aircraft satisfies this kind of trim flight, the control after each guidance function or during the guidance function will always follow the steady state trim value flight. This implies that the system will save its control efforts during the above flights, since
25 the system does not need to waste any control effort to hold extra forces or moments for altitude, airspeed, or angle of attack, or roll angle, or side slip angle, etc.

In order to achieve the above goals, a LQR model technique with command generator method is applied. However, instead of using a differential equation as command generator, the steady state trim value with its initial trim condition is employed as the command generator in the invention. The difference between current flight state, steady state trim value and initial trim condition is set to be the tracking error, which is minimized or reduced to zero while in the steady state condition.

Figure 7 illustrates the pitching angle steady state trim control law. The original initial trim condition is θ_0 , the desired steady state trim value from aerodynamic analysis is θ_{ss} , and the total pitching angle error per time step in the system will be θ_{err} . Note that the system disturbance rejection design is also included in this diagram, denoted as d_θ . A feedback command generator is used to provide the necessary control effort to move initial trim to steady state trim.

It is denoted that all initial trim values are evaluated for trim search control technique. These steady state trim values are transferred to a gain schedule table based on various airspeeds, and an example table is shown in Table III.

TABLE III: Example helicopter trim table

State	Airspeed	Value	Feedback Controller
v	Hover	0	Roll actuator
	40 Knots	-0.0690	
	80 Knots	-0.1970	
w	Hover	0	Collective actuator and pitch actuator
	40 Knots	2.170	
	80 Knots	5.425	
θ	Hover	1.5930	Collective actuator and pitch actuator

	40 Knots	1.7130	
	80 Knots	2.3040	
ϕ	Hover	-3.3630	Roll actuator
	40 Knots	-1.9460	
	80 Knots	-2.0760	
ψ	Hover	0	Yaw actuator
	40 Knots	0	
	80 Knots	0	

To make the system performance follow steady state reference, the tracking error will satisfy:

$$\varepsilon_{\theta} = (\theta_{ss} + \theta - \theta_0) + d_{\theta} \quad (10)$$

- 5 When transfer function of (11) applies for command generator, the modified tracking error equation will be transformed to

$$\varepsilon_{\theta} = \xi_{\theta} - \mu_{\theta} \quad (11)$$

where ε_{θ} is the modified tracking error with respect to pitching angle, θ . It is assumed that the command generator is of the form of closed loop aircraft system as

$$\begin{aligned} \dot{X}_{\mu} &= A_c X_{\mu} + B_{\mu} \mu \\ Z_{\mu} &= H_{\mu} X_{\mu} \end{aligned} \quad (12)$$

10 where X_{μ} and Z_{μ} are steady state search state and output variables. Note that θ is just one of performance outputs for example. It is very important to know that the command generator model is selected very close to the closed loop system of aircraft, where A_c is re-grouped from

$$A_c^{Long} = A - B_{long} R_{long}^{-1} B_{long}^T P_{long} \quad \text{and} \quad A_c^{Lat} = A - B_{lat} R_{lat}^{-1} B_{lat}^T P_{lat} \quad (13)$$

Closed loop eigenvalues of (13) are all stabilized from the inner loop equations.

Combination of the state equation and command generator results in

$$\dot{\bar{X}} = \begin{bmatrix} \dot{X} \\ \dot{X}_\mu \end{bmatrix} = \begin{bmatrix} A_c & 0 \\ 0 & A_c \end{bmatrix} \cdot \begin{bmatrix} X \\ X_\mu \end{bmatrix} + \begin{bmatrix} 0 \\ B_\mu \end{bmatrix} \cdot \mu = \bar{A}_c \bar{X} + \bar{B}_\mu \mu \quad (14)$$

- 5 The command generator along with LQR design is used to achieve the steady state loop design. It is assumed that the command generator control input satisfies the following differential equation:

$$\ddot{\mu} + a_1 \dot{\mu} + a_2 \mu + a_3 \mu = 0 \quad (15)$$

Therefore, its characteristic polynomial will be

$$10 \quad f_\mu(s) = s^3 + a_1 s^2 + a_2 s + a_3 \quad (16)$$

Note that eigenvalues of the above characteristic polynomial are pre-selected to be very stable.

Multiplying (14) by $f_\mu(s)$ (16) and assuming

$$\xi = f_\mu(s) \bar{X} = \ddot{\bar{X}} + a_1 \dot{\bar{X}} + a_2 \bar{X} + a_3 \bar{X} \quad (17)$$

$$15 \quad \eta = f_\mu(s) \mu = \ddot{\mu} + a_1 \dot{\mu} + a_2 \mu + a_3 \mu \quad (18)$$

results in

$$\dot{\xi} = \bar{A}_c \xi + \bar{B}_\mu \eta \quad (19)$$

Therefore, the modified tracking error on (11) can be transformed to

$$f_\mu(s) \cdot \varepsilon = [-C \quad C] \cdot \xi = \bar{C} \xi \quad (20)$$

- 20 where C is the matrix represented from the state and its trim variables and ε are all modified tracking errors. Therefore, this error motion can be represented in the following canonical form

- 22 -

$$\begin{aligned} \dot{\varepsilon} &= \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -a_3 & -a_2 & -a_1 \end{bmatrix} \cdot \varepsilon + \begin{bmatrix} 0 \\ 0 \\ \overline{C} \end{bmatrix} \xi = F\varepsilon + G\xi \\ e &= \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \cdot \varepsilon \end{aligned} \quad (21)$$

In order to achieve small error guidance without using too much control energy, state and command generator equations (19-20) are augmented with the above error representation (21) as:

$$\begin{bmatrix} \dot{\varepsilon} \\ \dot{\xi} \end{bmatrix} = \begin{bmatrix} F & G \\ 0 & \overline{A}_e \end{bmatrix} \cdot \begin{bmatrix} \varepsilon \\ \xi \end{bmatrix} + \begin{bmatrix} 0 \\ \overline{B}_\mu \end{bmatrix} \cdot \eta = \hat{A}_C \begin{bmatrix} \varepsilon \\ \xi \end{bmatrix} + \hat{B}\eta \quad (22)$$

In order to transform the above problem into LQR design, the cost function of the above system is designed as

$$J_{\varepsilon-\xi} = \frac{1}{2} \int_0^\infty \left\{ \begin{bmatrix} \varepsilon & \xi \end{bmatrix} \cdot Q_{\varepsilon-\xi} \cdot \begin{bmatrix} \varepsilon \\ \xi \end{bmatrix} + \eta^T \cdot R_{\varepsilon-\xi} \cdot \eta \right\} dt \quad (23)$$

where

$$Q_{\varepsilon-\xi} = \begin{bmatrix} I & 0 \\ 0 & \overline{C} \end{bmatrix}^T \begin{bmatrix} I & 0 \\ 0 & \overline{C} \end{bmatrix} \quad \text{and} \quad R_{\varepsilon-\xi} = I \quad (24)$$

Therefore, the solution of the control system will have the optimal tracking error controller as

$$\eta = -\hat{B}^T K_{\varepsilon-\xi} \begin{bmatrix} \varepsilon \\ \xi \end{bmatrix} \quad (25)$$

where $K_{\varepsilon-\xi}$ is the solution of the following Riccati equation

$$\hat{A}_C^T K_{\varepsilon-\xi} + K_{\varepsilon-\xi} \hat{A}_C + Q_{\varepsilon-\xi} - K_{\varepsilon-\xi} \hat{B}_{\varepsilon-\xi} R_{\varepsilon-\xi}^{-1} \hat{B}_{\varepsilon-\xi}^T K_{\varepsilon-\xi} = 0 \quad (26)$$

The above Riccati equation provides positive definite symmetric solution, because the system is stabilized first for all models. In addition, the model is from a canonical form of the error tracking polynomial. Therefore, the second LQR increases stability of the system not only in steady state trim but also in control authority and

disturbance rejection in the loop. This is shown in Figure 8 as wedge-shaped stability region 49.

Note that the above calculation can be simply programmed into the software as long as the original closed loop system is determined from the search routine in the inner loop. Therefore, the program to design the steady state search loop is interconnected with respect to the search routine in the inner loop to perform all at the same time, reducing the required engineering time in computing these.

Outer Loop Classic Guidance Design

This present invention improves the design of a flight guidance system (FGS) using classic feedback loop on the outer loop of the system. Both military and commercial requirements, as well as regulatory agencies, are considered, and customer inputs and Federal Aviation Administration (FAA) regulatory data are assumed to be pre-required and shall be considered in the design of flight guidance control systems.

Adjustment of individual control gain is dependent on its relative aerodynamic coefficients and associated control gains. The rules of adjusting these gains are not fixed. In order to correctly adjust these gains, several rules are needed so that the same mistakes are not repeated each time in the classic feedback guidance design. Since the inner loop LQR gain schedule design has stabilized the closed loop system, classic feedback control laws are mainly for guidance purpose. Of course, if the classic feedback laws will increase the stability of the system while performing very good guidance function, this kind of classic feedback control laws will be considered first. However, it has been observed that in high-speed flight conditions there are very few control gains that will make the system stable without employing LQR gains.

Since the closed loop is stable, adjustment of classic feedback gains can be simplified to emphasize increased guidance power. It has been determined that adding all their related gain values together and multiplying with a summary gain can increase guidance performance. This way of implementation may not work by the pure classic feedback control laws, but this method is one of the powerful initiations in guidance system with the present LQR design.

The methods of how to adjust these gains will be analyzed and discussed below per importance of individual block based on military or FAA requirements.

Directional and Lateral Guidance Control

Lateral path control can be accomplished over the full flight envelope of any conventional helicopter or airplane through roll attitude commands alone. Depending on forward speed and the nature of the yaw axis, commanded roll attitude will result in a heading rate for cruise flight or sideslip for hover or low speed flight. For aircraft equipped with direct lateral thrust control capability, low speed guidance performance will be highly enhanced through the proposed method.

Heading Control

For cruise flight, desired heading can be captured and tracked through roll attitude commands proportional to the heading error. The heading reference is typically provided from a selector knob on the FGS control panel. Heading error scheduled gain could be avoided as a function of true airspeed or groundspeed from the above LQR method. Therefore, it will become very easy to maintain an approximately constant ratio of commanded turn rate to degrees of heading error. No additional damping terms will be required using the proposed method. Important features of a heading select control system include attitude command limits for consistent maximum turn rates (standard rate is typical) and simplified command rate limiting and filtering for optimum ride qualities.

Figure 9 is a diagram of the YawSCAS [(22) in Table i] and shows the potential of yaw heading guidance control during low speed flight. The yaw guidance for fast speed and lower speed in the figure is determined by a switch called Y_Attsw 51. When Y_Attsw 51 logic is true, it is assumed the aircraft is at a low airspeed. Therefore, turn coordinate function is off. The guidance system to make aircraft turn will mainly contribute from yawing control instead of rolling. In other words, the rolling command will pick up.

This switch on or off is determined by a signal called Turn_Coord_On which is shown in Figure 10 on the diagram for RollHdgHold [(10) in Table I]. Determination of switching on-off Turn_Coord_On is dependent on the true

airspeed (TAS) logic shown on RollHdgHold (10) diagram. When TAS is between 35 and 40 knots, the system is on a hysteresis loop, depending on whether airspeed is decreasing or increasing. Yaw heading control in low speed is assumed that TAS is lower than 40 knots, which refers that Turn_Coord_on = 0, and Y_Attsw = 1.

5 Since improved LQR method has shifted all eigenvalues to the desired positions, the control gains used in this diagram are fixed and gain scheduling is avoided. In addition, all employed gain values have a ratio between 1/10 and 1/4. Again, this helps a designer to save time in adjusting these gains in the flight field.

10 When Y_Attsw = 1, Yaw_Actr_Cmnd 55 (Figure 9) gets its value from Psi_plus_r 57, the value of which value is determined by YawOuter [(23) in Table I]. The diagram of YawOuter (23) is shown in Figure 11. All gains on the YawOuter (23) diagram need to be pointed to the correct direction so that Yaw in the low speed region will be guided.

15 The first gain value discussed here is Yaw_Ay_Gain 59. Without Yaw_Ay_Gain 59 feedback, the system will diverge (during steady state turn or circle mode) when LQR Yaw Feedback control is not used. The sum of Ped_control will be very hard to keep in the unchanged value (zero). Usually, this gain value is set to be positive 1/10 to 1/4 of Psi_r_Gain 57 value.

Lateral Navigation Control

20 Lateral path guidance to a VOR or Localizer navigation source is accomplished by feeding back lateral deviation (cross-track error) into a heading-stabilized roll control loop. Here, the heading reference is the desired course to be followed. The angular VOR deviation signal should be converted to pseudo-linear cross track distance by use of DME or other appropriate estimate of distance to the transmitter. Localizer deviation may be linearized by use of radar altitude whenever
25 glideslope control is concurrent, with maximum usable sensitivity being dependent on sensor noise content. Use of supplementary sensors (inertial, air data, e.g.) as available without complementary or optimal state filtering is highly admissible with the present design. When the navigation system is expected to overfly a VOR
30 station, the system design should include an automatic dead-reckoning mode to take over when the indeterminate area of coverage ("zone of confusion") is encountered.

Of particular importance in a lateral path guidance implementation is the capture sequence. Unlike pure classic feedback system, the proposed design can be automatically held in heading select mode.

FMS Navigation Control

5 Off-the-shelf Flight Management Systems (FMS) typically provide a pre-processed "composite" roll attitude steering output, which supplants the necessity for detailed control law implementation in the FGS. However, the adequacy of such commands can be avoided for the intended application, in particular where the steering output may have been tailored to a different class of aircraft or speed
10 envelope. Limiting and filtering characteristics of the composite command should be examined for suitability to the application and supplemented in the FGS as necessary.

Lateral Go-Around Function

15 Lateral Go-Around (also sometimes referred to as Missed Approach or Egress) for the lateral axis consists of establishing a suitable lateral path or heading for exiting the landing area. Typically, maintaining heading existing at engagement is considered acceptable. Subsequent turning to the preset missed approach heading is typically accomplished by engagement of the heading select mode at pilot option. With the present invention, the lateral heading will preferably be automatically
20 engaged when mission is missed.

Vertical Guidance Control

25 Guidance of the vertical flight path of a helicopter or VTOL aircraft, such as a tiltrotor, is accomplished through pitch attitude or power commands, depending on the flight regime. At cruise speeds, climbs and descents are best achieved by changes in pitch attitude, whereas at low speeds (below V_y), control can only be affected through power (vertical thrust) changes. Depending on the application and cost goals, a thrust axis can be implemented automatically so that the coupling effect from lateral and longitudinal motions as well as disturbance can be reduced to minimum.

The vertical FGS are designed to provide a smooth transition between control strategies at the appropriate airspeed (or other parameter, such as thrust angle, as applicable). Barometric vertical velocity, preferably complemented with inertial vertical velocity or acceleration, typically forms the basis of all vertical path control modes. Path errors (altitude, glide slope, etc.) are closed around this inner loop, thus providing a vertical velocity reference or command. The percentage of accuracy of vertical flight path capture can be reached to 99.9 in the present invention. This is attributed to separation of control law design in helping guidance accuracy.

Vertical Velocity Control

Implementation of vertical velocity select/hold mode requires the generation of a vertical velocity error feedback comprised of the difference between a reference and vertical velocity for climb and descent commands. The reference is preferably supplied by a selector knob (or wheel) located on the FGS control panel or through a "beep" switch located on a control stick grip (preferably the power lever) that slews a reference integrator within the FGS. Rate and magnitude limits are designed on the reference consistent with the maneuver limits desired. Synchronization of the reference to existing vertical velocity will be engaged automatically. The accuracy of vertical velocity synchronization is higher than 99 percent by using the method of the invention.

Altitude Control

Implementation of altitude control modes consists of generating a reference altitude, subtracting this reference from existing altitude, and providing the error as a reference (command) to the vertical velocity control loop. Altitude hold mode will store the value of altitude existing at engagement as the reference. Altitude pre-select mode employs the reference to be supplied externally, usually from a knob on the FGS control panel or the altitude instrument panel display. The method for implementing pre-select control is to arm the mode and continue in a climb/descent mode (vertical speed e.g.) until the selected altitude is neared. An asymptotic capture is automatically programmed as a function of altitude closure error, followed by automatically switching to altitude hold. Maneuver limiting provisions for vertical

speed mode is applied for altitude control as well, except more restrictive limits on maximum allowable vertical speed may be appropriate.

Vertical Glideslope Capture

5 Implementation of a glideslope control law is similar in structure to altitude hold, although somewhat higher tracking gains are desirable. For conventional ILS systems, which provide angular deviation signals, conversion of the errors to linear displacement is needed, typically using radar altitude to estimate distance from the transmitter. Since staying on the glideslope requires maintaining a descent rate, the vertical speed command includes a down command bias based on horizontal speed
10 so that no steady state glideslope error will be required to achieve the descent. As in lateral navigation, the capture sequence is designed to produce an asymptotic acquisition of the beam without overshoots or undershoots.

Vertical Transition-To-Hover

15 Approach to hover in the vertical axis consists of setting up a controlled descent to the desired radar altitude. The descent angle is dependent on operational requirements, with approximately six degrees being typical for helicopters or tiltrotor aircraft. The altitude rate reference is computed based on horizontal ground speed to achieve a constant angle glide path, concluding in a closed loop flare to the established height above ground or water. Capture and track
20 of the final altitude is similar to that used for altitude select/hold. Radar altitude can be complemented with inertial vertical acceleration or velocity to eliminate effects of noisy signals and/or terrain variations.

Vertical Go-Around

25 Vertical go-around mode consists of establishing a climb rate that is sufficient to exit the landing area in a safe manner. A fixed vertical velocity reference is usually sufficient, with 750 ft/min being typical. If the mode is engaged at speeds below V_y , the command will need to be delayed. However, it has been ensured that the desired climb angle can be achieved and maintained without exceeding power limits programming horizontal speed to the system.

Longitudinal Guidance Control

30

Longitudinal guidance consists of controlling airspeed or groundspeed along the x-axis of the vehicle. Like the vertical axis, control is usually through pitch attitude or power commands, depending on flight condition. At speeds below V_y , speed control is typically accomplished by commanding pitch attitude changes.

5 Thrust vector angle or direct longitudinal thrust modulation (if available) are also effective for low speed control. At cruise, power modulation is effective for maintaining desired speed. Transition between control strategies is linked with the vertical axis, exchanging between pitch and power control simultaneously for both longitudinal and vertical modes.

10 **Airspeed/Ground Speed Control**

Implementation of speed select/hold mode requires the generation of a velocity error feedback comprised of the difference between a reference and current speed to provide accelerate or decelerate commands. For airspeed control, pitot-derived airspeed is complemented with inertial longitudinal acceleration. Depending

15 on vehicle characteristics, a moderate level of acceleration feedback is employed to attain desired stability levels. The reference is supplied by a selector knob located on the FGS control panel, or through a beep switch located on a control stick grip (preferably the cyclic stick), which slews a reference integrator within the FGS computations. The reference is rate and magnitude limited consistent with the maneuvering limits desired. With this design, the accuracy of airspeed control is

20 higher than 99 percent.

Longitudinal Transition-To-Hover

Automatic approach to hover in the longitudinal axis is implemented by controlling groundspeed in a predetermined manner. If termination of the approach

25 is to be at a specific (geographic) position, distance to the hover point is used to control the deceleration initiation and magnitude such that zero velocity is reached simultaneously with zero distance. The speed reference is commanded at a rate consistent with the desired maximum deceleration rate (typically 1 to 2 knots/second). If the hover point is not specific, the pilot can initiate the approach at

30 any time, whereupon the velocity reference is commanded to zero at a constant rate, again consistent with the desired maximum deceleration rate.

Longitudinal Go-Around

Go-Around in the longitudinal axis is implemented by commanding a controlled acceleration to the optimum climb speed. The controlled parameter may be either groundspeed or airspeed as appropriate for the particular approach mode being aborted. All control law parameters established for speed control and transition to hover are also applicable to go-around.

DISCUSSION AND RESULTS

In the old classic feedback control laws, proportional-integral-derivative (PID) method is applied to not only control the aircraft but also stabilize the system. Feedback to the individual performance may repeatedly be employed for the other performance to achieve stabilization, guidance and navigation. Since integral gains are used, washout out functions and limiter release logics are necessarily employed to avoid control surfaces quickly hitting their detent values for protections. Therefore, in military specification, as long as frequencies of slow mode eigenvalues is very slow, negative damping ratios are under certain values, the system can still exist in the old classic feedback control laws design. When asking for precision control, the ability of this kind of control method may or may not achieve this goal, depending on aircraft's structural and aerodynamic design.

The proposed method is to employ the other two assistances from LQR to allow the aircraft system to achieve precision control even that the open loop system is not within military category. Therefore, the trim condition, disturbance rejection and handling qualities scale ratio can all be considered as requirements in this three loop control laws design. Therefore, the performance in guidance, navigation and stability are extremely improved.

Improved LQR Method

The advantages of proposed method in improved LQR:

1. Shift all closed loop eigenvalues and eigenvectors to the desired positions and directions for all models from $k = 0, 1, 2, \dots$, or j . Therefore, all characteristics of individual states will perform similarly.

2. All gain values are pre-programmed using search algorithm. The engineering time of searching all gains will be reduced. The time to switch to another set of gains values is also shortened.
3. It will ensure that the closed loop eigenvalues and eigenvectors are all located on handling quality level scale 1.
4. Since all gains from improved LQR are stabilized, simplified classic guidance law will not need to do the gain adjustment or gain scheduling any more.
5. Simplified classic feedback gain can be used for all models in guidance loop.

Steady State Search Method

The advantages of proposed method in steady state search method:

1. Allow the aircraft to fly the natural trimmed conditions at all times. Therefore, the additional control authority that would be used for balancing trim values can be reserved.
2. Since no zeros at the poles of disturbance rejection model are in the search method, a certain degree of disturbance rejection is achievable.
3. Simultaneously achieving guidance, navigation, stability, and control of aircraft under the optimal performance with disturbance rejection. Therefore, the accuracy of guidance functions is extremely improved.

Classic guidance System

The advantages of the methods of the invention in classic feedback method:

1. The feedback states for certain functions in guidance loop can be eliminated. Since LQR has stabilized the closed loop system, the old classic feedback states to make the system stabilized can be eliminated. This will simplify the guidance loop to be more concise.

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2. This loop will ensure the aircraft follows the best trim condition on all necessary maneuvers.
3. This loop will increase the control authority for all other loops.
4. This loop will increase aircraft stability in steady state level flight.
5. This loop will help to steady state error correction.

Simulation Results

UAV simulation results are employed to illustrate the potential of the proposed system of the invention. Figure 12 shows a square flight path 61 used in the simulation. This type of flight path might be used for a rescue searching function or similar mission. The aircraft flies from waypoint #1 at origin 63 [located at (0,0)], then sequentially flies to waypoints #2, #3, #4, and #5 on the perimeter of flight path 61 before returning to waypoint #6, which is also at origin 63. In the simulation, when the aircraft flies to each waypoint, it will transform its flight on the waypoint to a circle mode until the ground station ensures that no victim is located near that waypoint.

UAV simulation results are shown on Figures 13, 14, 15 and 16 for different searching speeds and searching square sizes. Figure 13 shows the results of a flight at 80 knots around a flight path 4 miles on each side, Figure 14 shows the results for a flight at 65 knots around a flight path 10 miles on each side, Figure 15 is for 45 knots around a 4-mile square, and Figure 16 is for 25 knots around a 2-mile square. Note that for airspeed higher than 40 knots, the turn coordinate function will be automatically turned on. Therefore, on each waypoint, circle mode will be performed until next waypoint is triggered. It is shown that UAV accomplishes its mission with higher than 99 percent accuracy of the waypoint capture on all six waypoints on all three cases where the airspeed is higher than 40 knots. Furthermore, the circle function is very well performed on each waypoint. Note that when flying circle mode, the aircraft altitude is also moving up and down to allow version system to explore any angle around the search region. Even with control surface changes in the vertical portion, the UAV still shows very positive flight. All guidance gains employed to accomplish the above flight are not gain scheduling,

which means they are not changed. Therefore, it can be observed that gain-scheduling function is avoided on the guidance loop.

Note that disturbance model is also added in the simulation system. When moving wind disturbance up to 10 knots on x and y directions, the aircraft is still performing very robust. Even with wind disturbance being increased to as high as 25 knots, the aircraft can still accomplish its mission without any assistance from other control algorithm.

Pure classic feedback control laws are also investigated in this model. It is recognized that classic feedback control laws require immediate attention for waypoint capture, and it can lose its flight path very easily. Flight control surfaces can reach their limits very easily because the open loop of the selected aircraft model is very unstable. When classic feedback control laws are going to

- (1) Stabilize the system,
- (2) Do the guidance and navigation of aircraft, and
- (3) As well as maintain natural flight trim conditions,

without gain scheduling, these functions become impossible. In addition, finding these gain values becomes time consuming and may not succeed.

The reasons for the proposed method easily accomplishing this mission are

- 1) Using three control loops to achieve its missions
- 2) Each loop performs its own best capability
- 3) Each loop will not affect other's performance
- 4) All closed loop eigenvalues from improved LQR method are located closely each other.
- 5) All close loop eigenvectors are having the same directions.
- 6) All trim values for search loop are from its natural performance.
- 7) Steady state error accumulation does not exist.

- 8) Classic feedback is for guidance purpose.

Figure 16 illustrates the effects when the helicopter flies slower than 35 knots and the turn coordinate function is off. The circle function does not exist under this condition. When asking the helicopter to do the search function on each waypoint, the aircraft will either transfer this mode to circle mode or an 8 mode. However, in either mode of flight the aircraft maintains its waypoint capture and square search mission.

In an alternate embodiment of the present invention, two LQR's, or one LQR and one H-infinity control, or two H-infinity controls, are utilized instead of one LQR plus classic feedback. However, this alternate embodiment may have the following disadvantages: (1) increase complexity of approach; (2) visibility of simulation of the whole system may be lost; and (3) individual guidance control law may be lost. Nevertheless, the steady state trim search control law, which is not found in any other control system, is retained.

Inside the rotorcraft industry, the present invention could be used on all manned or unmanned helicopter to robustly enlarge flight stability and improve flight quality. Outside the rotorcraft industry, this invention can also be applied to the fixed-wing aircraft, unmanned aerial vehicles, submarine autopilot systems, and other control systems.

The present invention includes significant benefits and advantages, including: (1) increasing handling qualities and performance for piloted aircrafts; (2) increasing robustness for unmanned aircrafts; (3) reducing flight test time; (4) reducing flight control law development time; (5) providing for easily applied intelligent portion for unmanned control; (6) providing for the system to be easily understood and implemented by engineers; and (7) using all advantages from classic feedback and modern control methods and eliminating their disadvantages.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description.

- 35 -

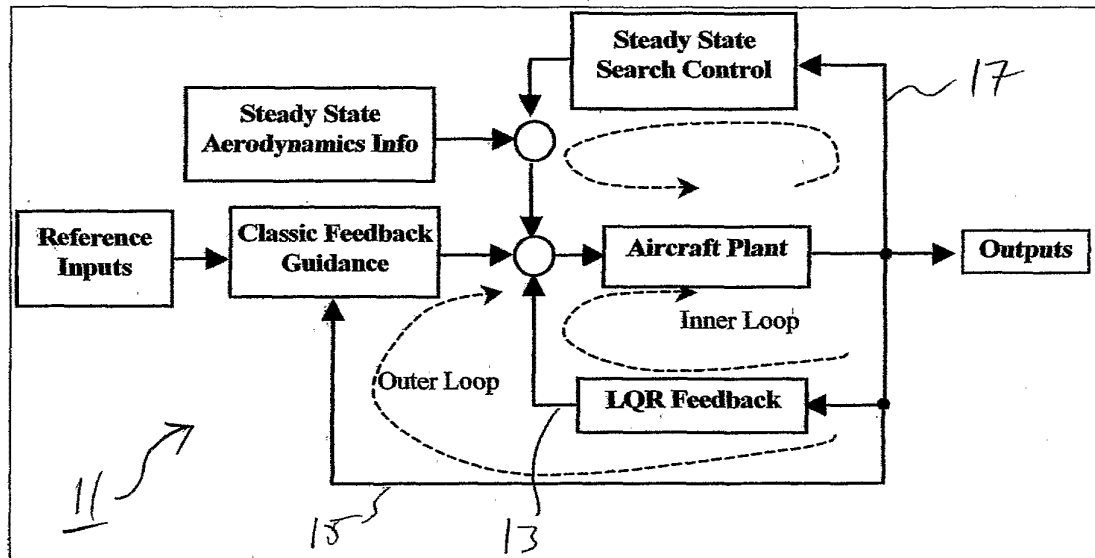
Claims

1. A flight control system for controlling the flight of an aircraft, the system comprising:

a first feedback loop using a linear quadratic regulator search method;

5 a second feedback loop using a classic feedback summary gain design; and

a third feedback loop comprising a steady state trim search method.

**Figure 1**

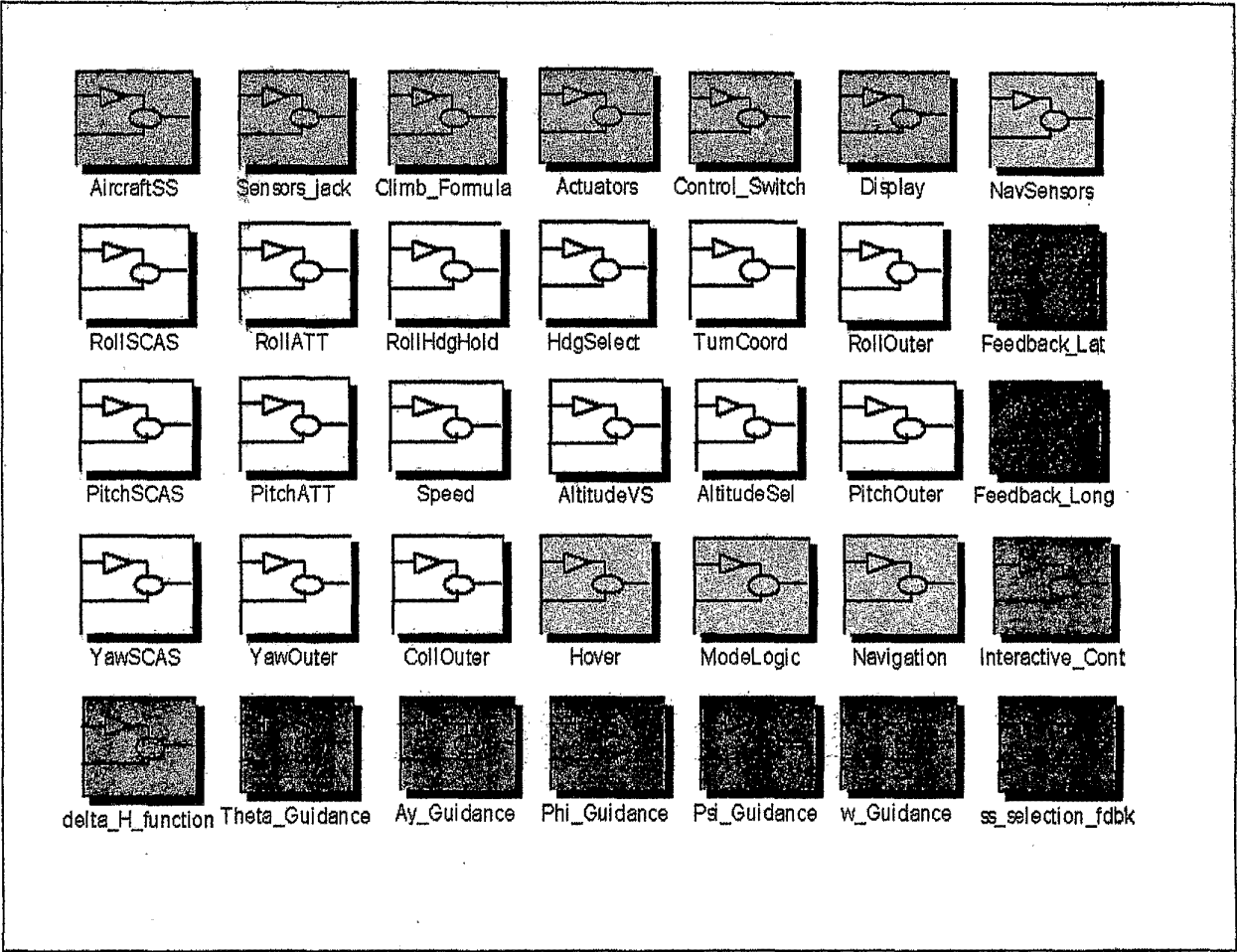
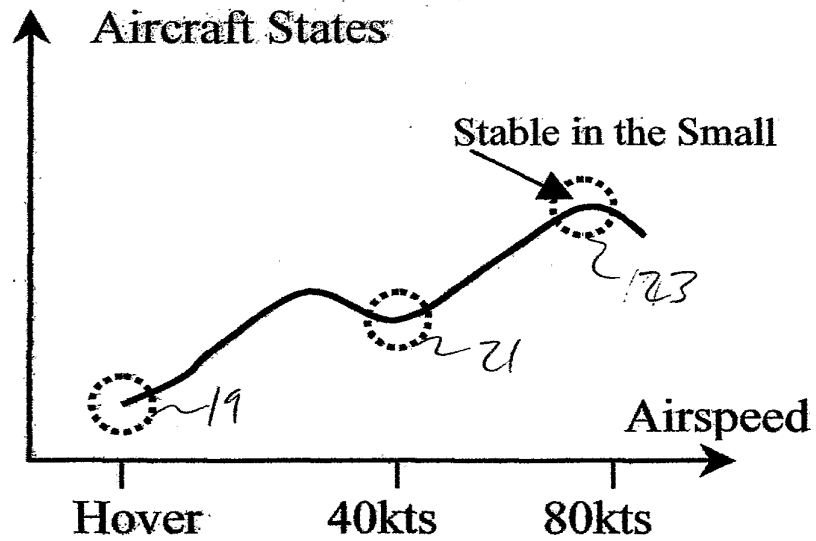
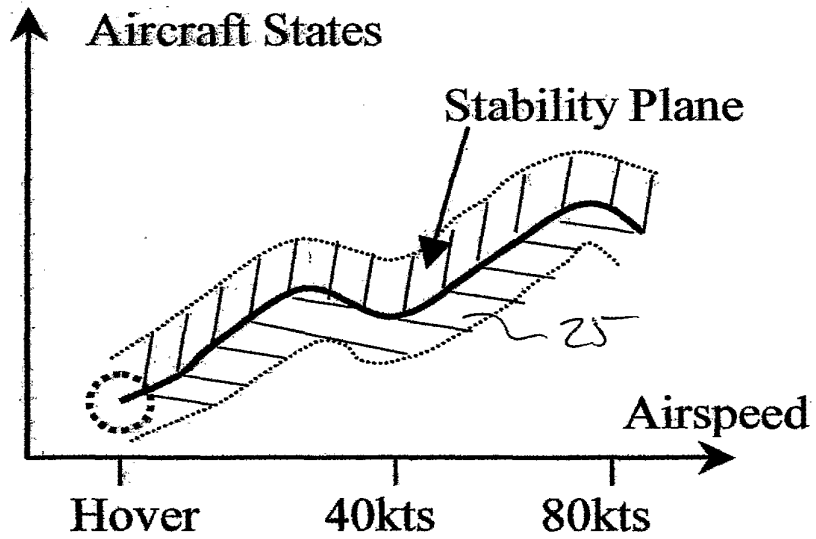
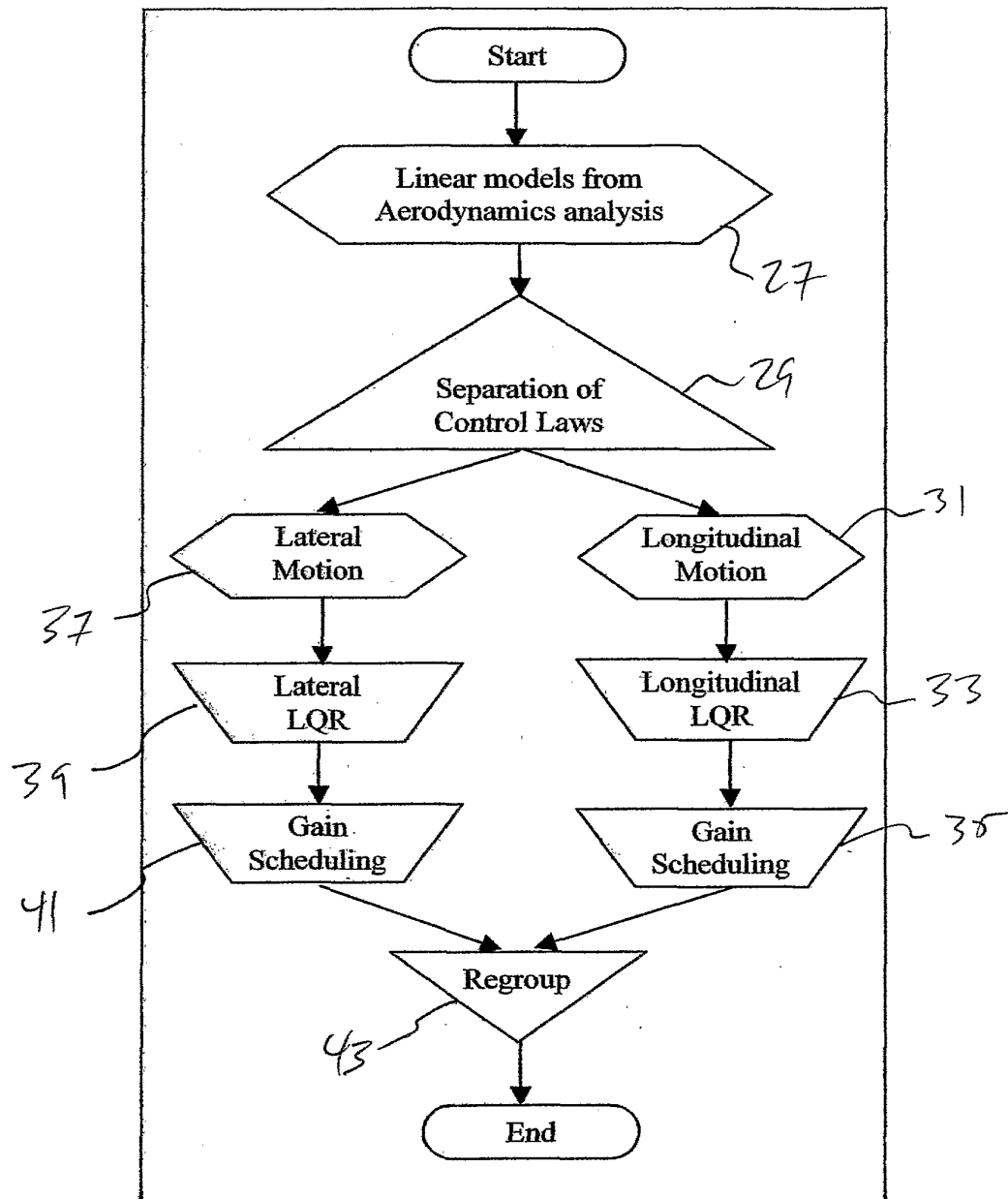


Figure 2

**Figure 3****Figure 4**

**Figure 5**

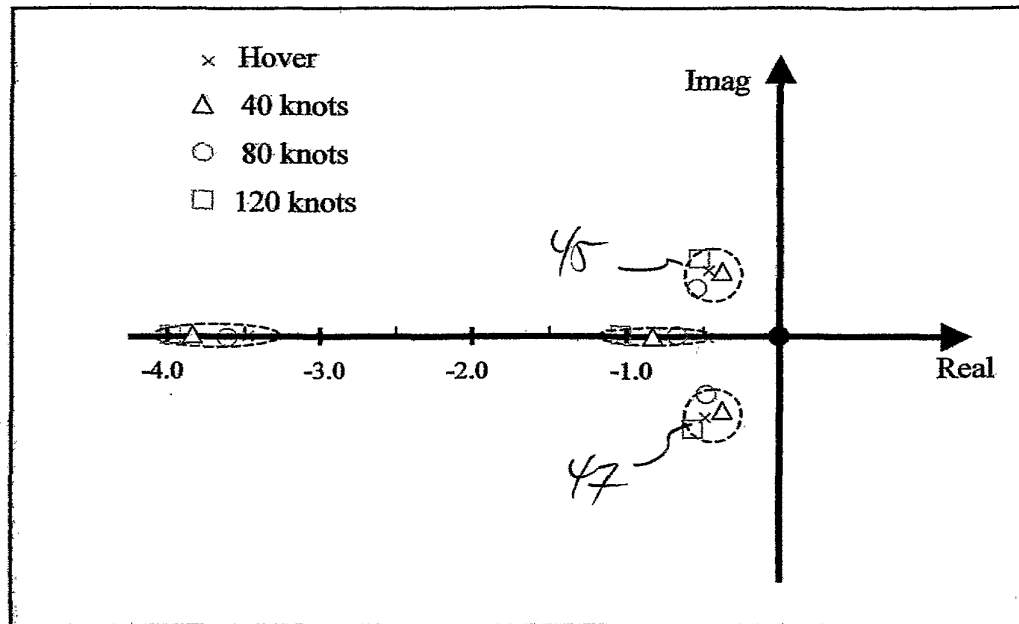


Figure 6

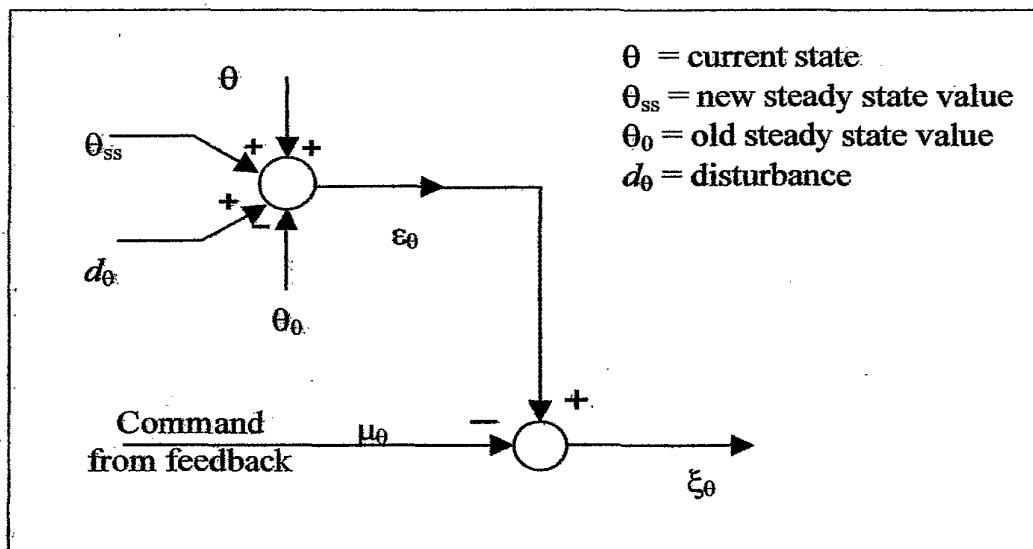
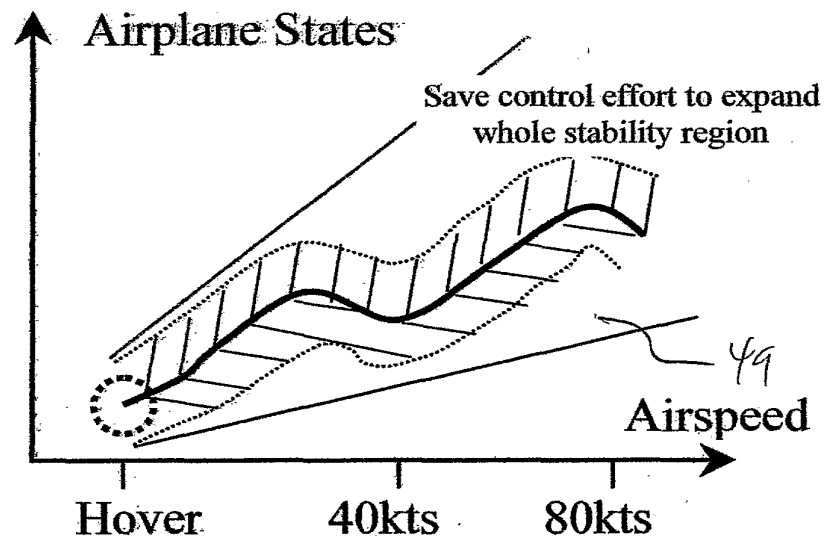


Figure 7

**Figure 8**

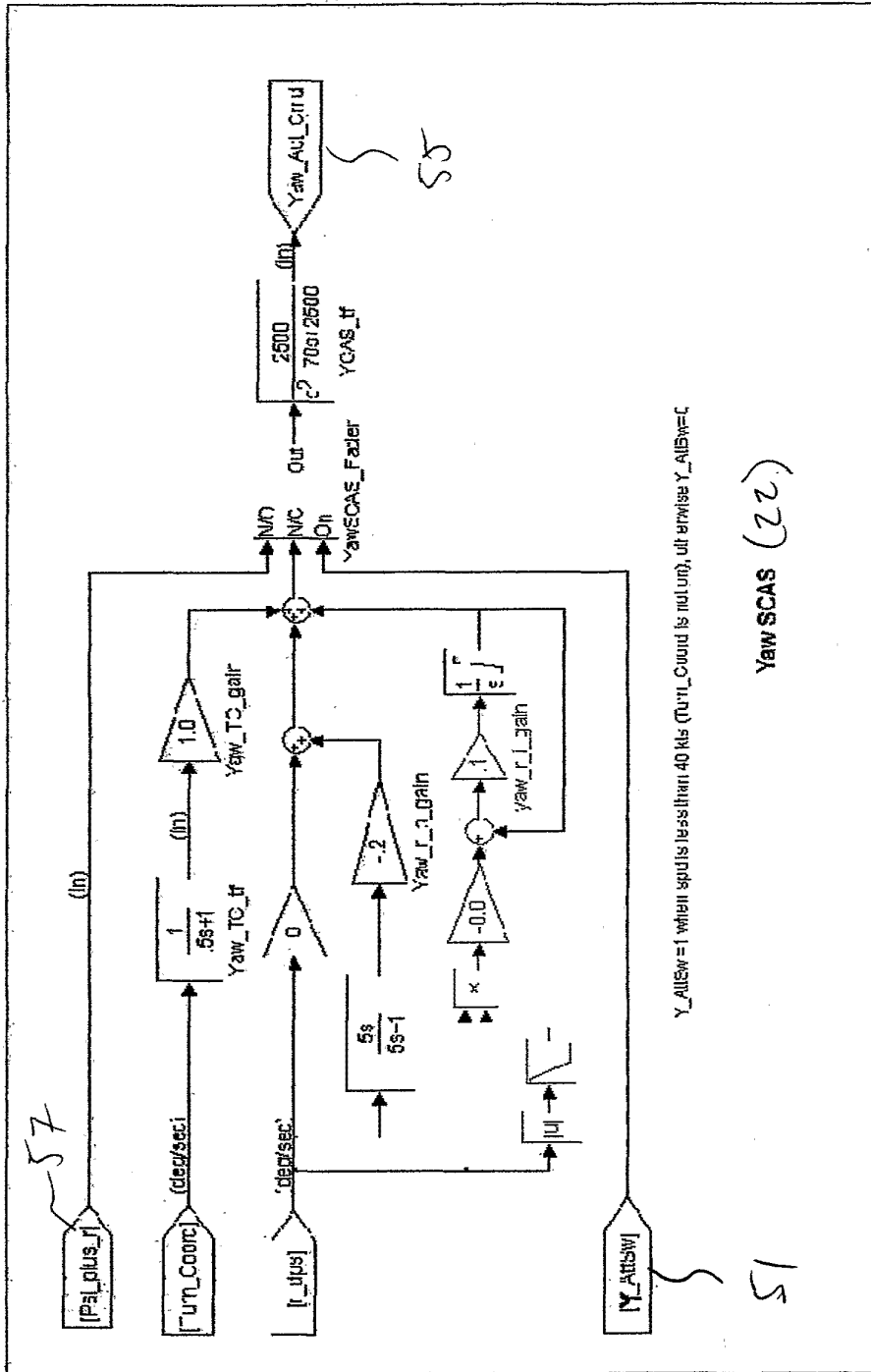


Figure 9

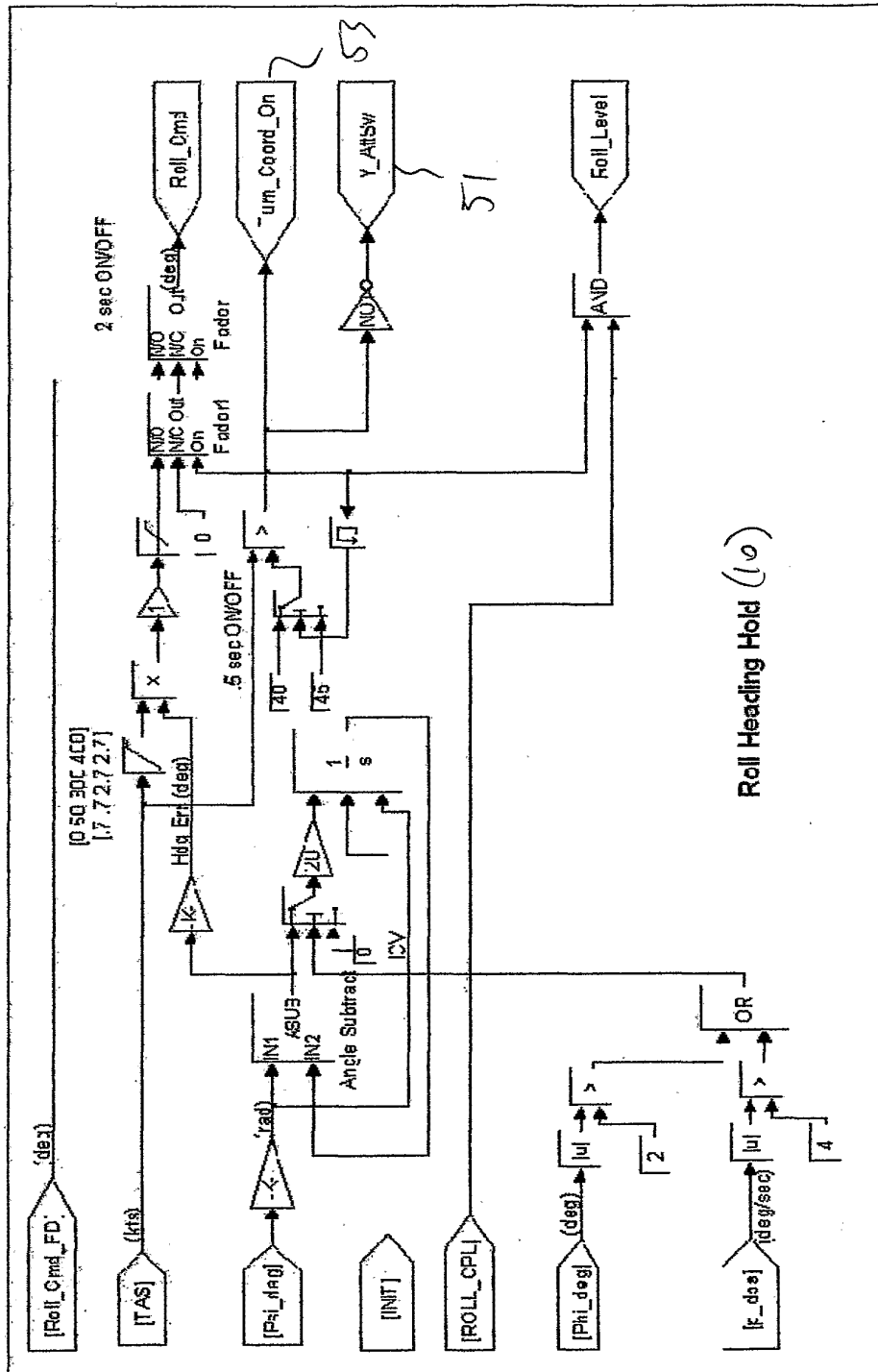
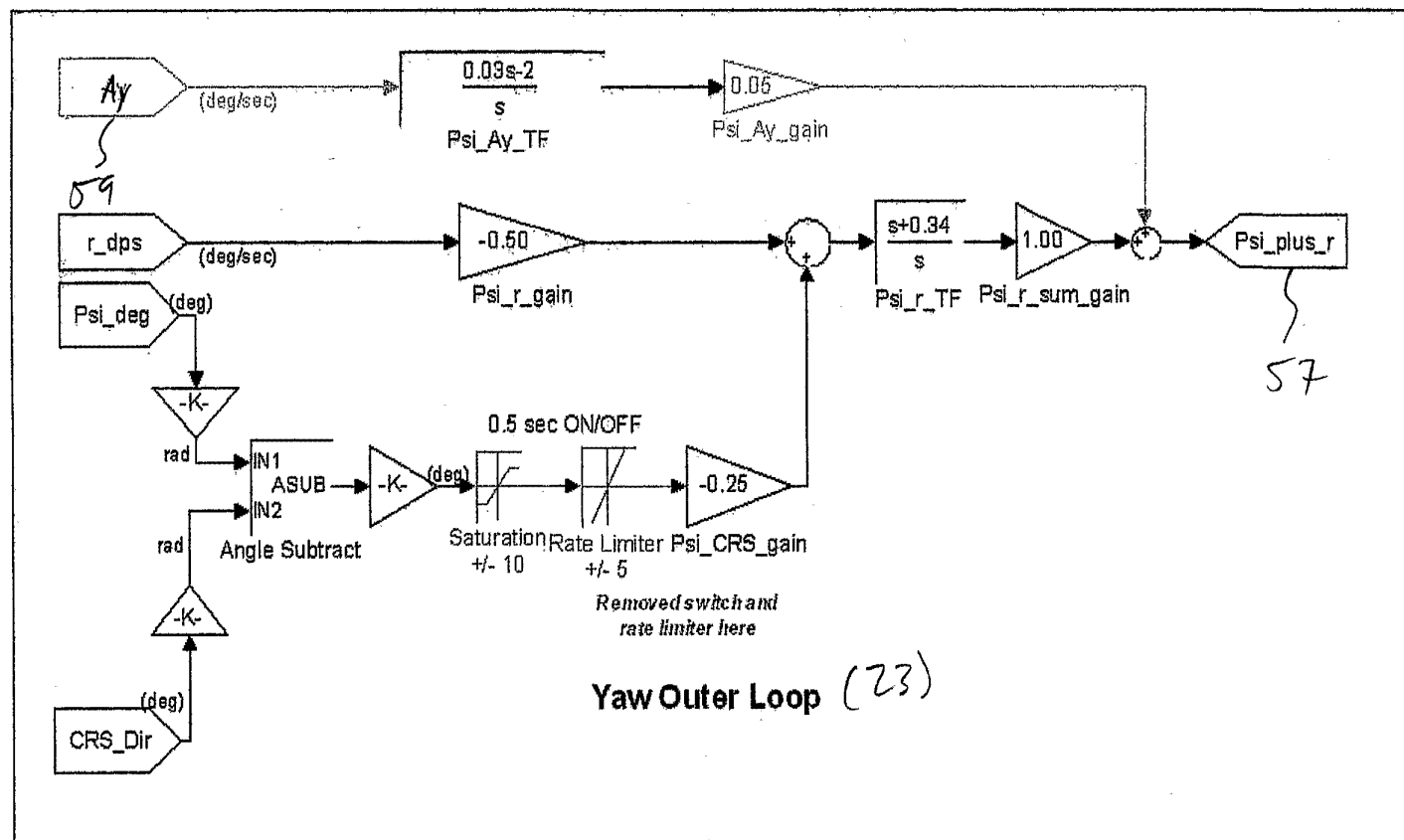
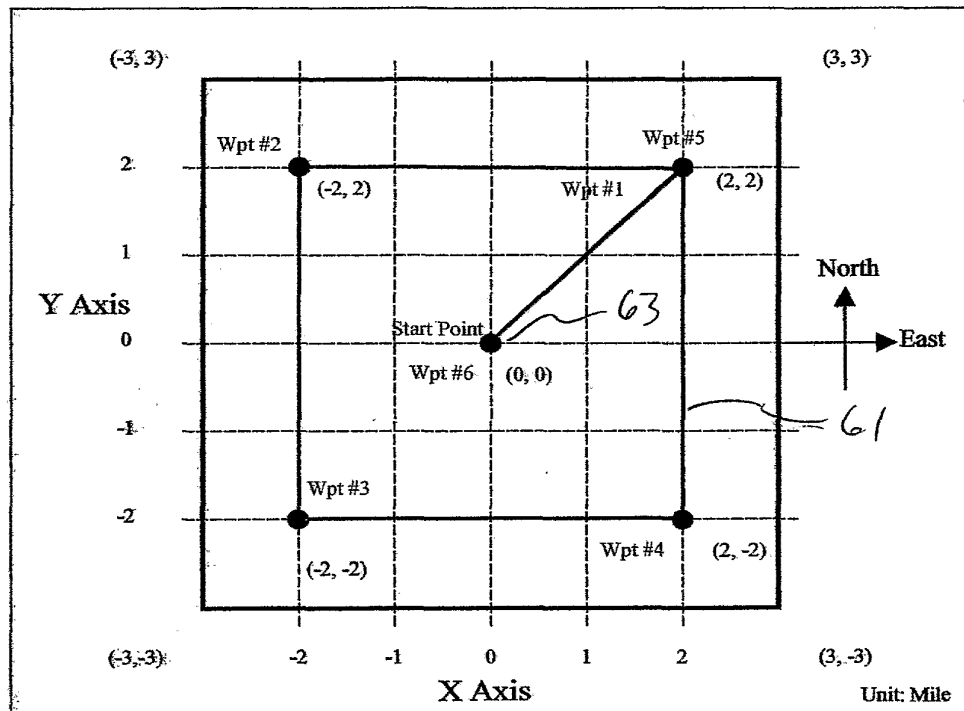
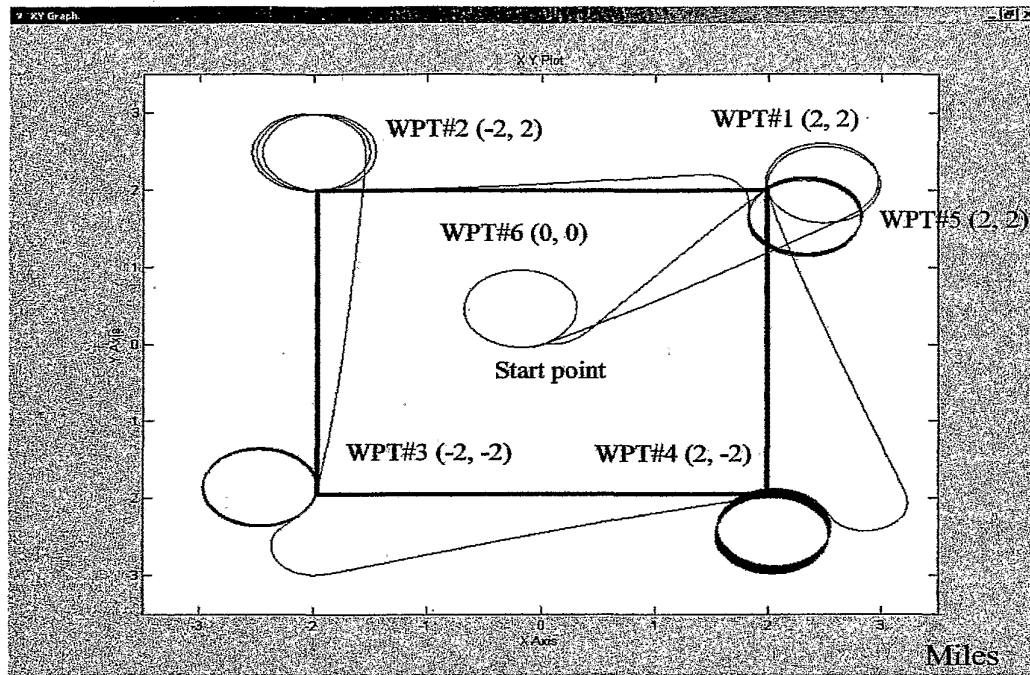


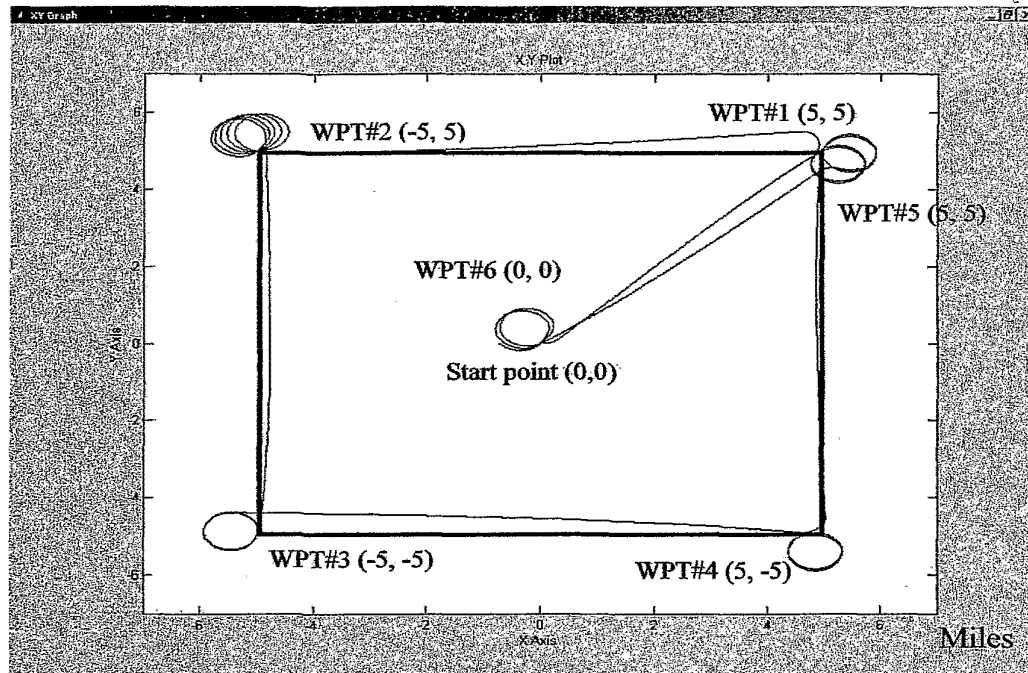
Figure 10

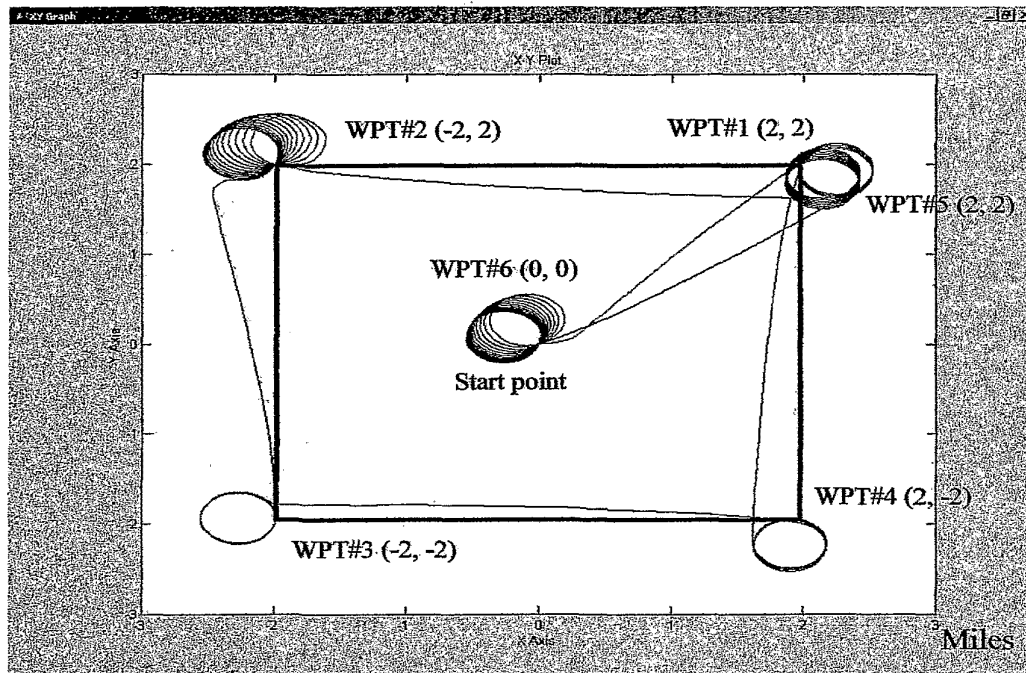
Figure 11

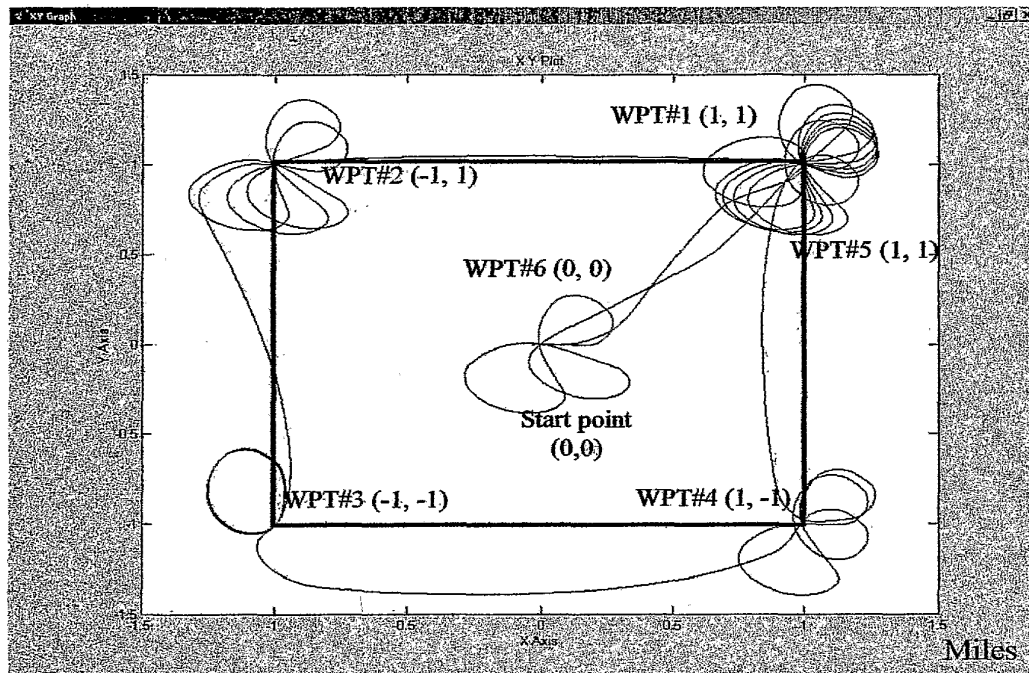


**Figure 12**

**Figure 13**

**Figure 14**

**Figure 15**

**Figure 16**

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: JAMES WALTON
LAW OFFICES OF JAMES E. WALTON, P.L.L.C
1169 N. BURLESON BLVD., SUITE 107-328
BURLESON, TX 76028

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 0837RF-H793P	Date of mailing (day/month/year) 26 AUG 2011
International application No. PCT/US2011/030498	International filing date (day/month/year) 30 March 2011
Applicant BELL HELICOPTER TEXTRON INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

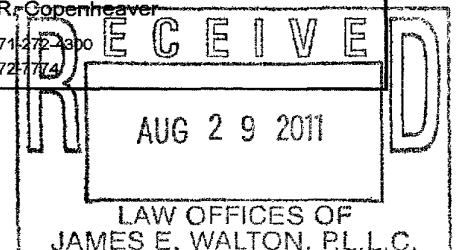
Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer Blaine R. Gopenheaver PCT Helpdesk: 571-272-1300 Telephone No. PCT OSP: 571-272-1774
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Form PCT/ISA/220 (July 2010)



PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 0837RF-H793P	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2011/030498	International filing date (<i>day/month/year</i>) 30 March 2011 (Earliest) Priority Date (<i>day/month/year</i>)
Applicant BELL HELICOPTER TEXTRON INC.	

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of:

- ☒ the international application in the language in which it was filed.
- ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

- ☒ the text is approved as submitted by the applicant.
- ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

- ☒ the text is approved as submitted by the applicant.
- ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

- a. the figure of the **drawings** to be published with the abstract is Figure No. 7
- ☒ as suggested by the applicant.
- ☐ as selected by this Authority, because the applicant failed to suggest a figure.
- ☐ as selected by this Authority, because this figure better characterizes the invention.
- b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2011/030498

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G05D 1/10 (2011.01)

USPC - 701/3

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - F02C 3/10, 9/28; G05D 1/00, 1/02, 1/10; G06F 7/00, 19/00 (2011.01)

USPC - 244/3.21, 76, 164; 701/1, 3, 4, 7, 10, 301

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

ECLA - B64C 13/16; G05D 1/06B2B, 1/10B

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Patbase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2008/0234881 A1 (CHEREPINSKY et al) 25 September 2008 (25.09.2008) entire document	1-20
A	WO 2007/018572 A2 (SHUE et al) 15 February 2007 (15.02.2007) entire document	1-20
A	US 2003/0191561 A1 (VOS) 09 October 2003 (09.10.2003) entire document	1-20

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

09 August 2011

Date of mailing of the international search report

26 AUG 2011

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

To: JAMES WALTON
LAW OFFICES OF JAMES E. WALTON,
P.L.L.C
1169 N. BURLESON BLVD., SUITE 107-328
BURLESON, TX 76028

Date of mailing
(day/month/year)

26 AUG 2011

Applicant's or agent's file reference
0837RF-H793P

FOR FURTHER ACTION

See paragraph 2 below

International application No.

PCT/US2011/030498

International filing date (day/month/year)

30 March 2011

Priority date (day/month/year)

International Patent Classification (IPC) or both national classification and IPC

IPC(8) - G05D 1/10 (2011.01)

USPC - 701/3

Applicant **BELL HELICOPTER TEXTRON INC.**

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US
Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Date of completion of this opinion

09 August 2011

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (July 2011)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2011/030498

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:
 - ☒ the international application in the language in which it was filed.
 - ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).
2. ☐ This opinion has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:
 - a. (means)
 - ☐ on paper
 - ☐ in electronic form
 - b. (time)
 - ☐ in the international application as filed
 - ☐ together with the international application in electronic form
 - ☐ subsequently to this Authority for the purposes of search
4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2011/030498

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	None	NO
Inventive step (IS)	Claims	1-20	YES
	Claims	None	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-20 meet the criteria set out in PCT Article 33(2)-(3) because the prior art does not teach or fairly suggest certain subject matter in the claims, as follows:

As to Claim 1, the prior art of record, individually or in combination, does not teach or fairly suggest an aircraft, comprising a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft; an actuator carried by the aircraft, the actuator being utilized to control the directional movement of the aircraft; and a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having: a model adapted to decouple the directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion; a lateral control architecture in data communication with the model, the lateral control architecture being adapted to utilize the lateral equation of motion to control the lateral motion of the aircraft; a longitudinal control architecture in data communication with the model, the longitudinal control architecture adapted to utilize the longitudinal equation of motion to control the longitudinal motion of the aircraft; and an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture; wherein the initialization command logic selectively activates the lateral control architecture for controlling the lateral motion of the aircraft and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft; and wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control speed variations of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

As to Claim 11, the prior art of record, individually or in combination, does not teach or fairly suggest a method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising sensing the speed variation of the aircraft with a sensor carried by the aircraft, the speed variation having: a longitudinal direction of motion; and a lateral direction of motion; controlling the speed variation of the aircraft with actuators operably associated with the aircraft; providing a control system in data communication with the aircraft sensor and operably associated with the actuators, the control system having: a model; a lateral control architecture; a longitudinal control architecture; and an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture; decoupling the directional movement of the aircraft into the lateral equation of motion and the longitudinal equation of motion with the model; controlling the lateral direction of motion with a lateral control architecture, the lateral control architecture utilizing the lateral equation of motion; controlling the longitudinal direction of motion with a longitudinal control architecture, the longitudinal control architecture utilizing the longitudinal equation of motion; and selectively activating the lateral control architecture and the longitudinal control architecture with the initialization command logic; wherein the control system receives sensed speed variation data from the sensor and operably controls the actuators, thus providing selective control of the yawing turns of the aircraft while maintaining a constant vector across a ground surface.

Claims 2-10 and 12-20 depend from base Claims 1 and 11, respectively, and therefore have novelty for at least the same reasons as do base Claim 1 and 11.

(Continued in Supplemental Box)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:

Box V

The following prior art is made of record to support and further define the reasons for allowance of base Claims 1 and 22:

(i) Cherepinsky et al. disclose an aircraft (fig. 1), comprising: a sensor carried by the aircraft (32 fig. 3), the sensor being adapted to sense a directional movement of the aircraft (sensor 32 output includes vertical acceleration 94 and vertical velocity, fig. 3); an actuator carried by the aircraft (servos 50 and tail rotor servos 54, fig. 2), the actuator being utilized to control the directional movement of the aircraft (servos control main rotor 12 and tail rotor 14, fig. 2 para. [0032]); and a control system (flight control system 16, fig. 3) in data communication with the aircraft sensor and operably associated with the actuator (para. [0030] Referring to Fig. 2, the flight control system 16 includes ... includes a Primary Flight Control System (PFCS) 22 and a Flight Augmentation and Cueing System (FACS) 24. The PFCS and FACS each receive the force output command signals of a collective controller 18 on line 20, a cyclic controller 28 on lines 30, and the aircraft's sensed parameter signals from sensors 32, on lines 34), the control system having: a model (para. [0030] Referring to Fig. 2, the flight control system 16 includes a model following control system which shapes the pilot's controller and displacement commands through an inverse vehicle model to produce the desired aircraft response). Cherepinsky et al. does not teach, either alone or in combination with the prior art of record, a model is adapted to decouple the directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion; a lateral control architecture in data communication with the model, the lateral control architecture being adapted to utilize the lateral equation of motion to control the lateral motion of the aircraft; a longitudinal control architecture in data communication with the model, the longitudinal control architecture adapted to utilize the longitudinal equation of motion to control the longitudinal motion of the aircraft; and an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture; wherein the initialization command logic selectively activates the lateral control architecture for controlling the lateral motion of the aircraft and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft; and wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control speed variations of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

(ii) Shue et al. disclose a model (represented by in flowchart form in fig. 5) related to flight control of an aircraft (pg. 1, Ins. 4-6) adapted to decouple (block 29 separates into longitudinal motion 31 and lateral motion 37 components, fig. 5) a directional movement of the aircraft (equation 1, pg. 11, models an aircraft based on airspeed, pg. 11, Ins. 12-13) into a lateral equation of motion (equation 2, pg. 12) and a longitudinal equation of motion (equation 3, pg. 12); a lateral control architecture (lateral LQR 39, fig. 5 and pg. 11, Ins. 5-6, is a linear quadratic regulator as described on pg. 12, Ins. 13-17) in data communication with the model (lateral motion component 37 is in communication with model of fig. 5), the lateral control architecture being adapted to utilize the lateral equation of motion (lateral motion component 37 is an input for lateral LQR 39, fig. 5) to control the lateral motion of the aircraft (the LQR method of fig. 5 is what is used in the LQR feedback block of fig. 1, the result of which goes to outputs block of flight control system in fig. 1); a longitudinal control architecture (longitudinal LQR 33, fig. 5 and pg. 11, Ins. 6-8, is a linear quadratic regulator as described on pg. 12, Ins. 13-17) in data communication with the model (longitudinal motion component 31 is in communication with model of fig. 5), the longitudinal control architecture adapted to utilize the longitudinal equation of motion (longitudinal motion component 31 is an input for longitudinal LQR 33, fig. 5) to control the longitudinal motion of the aircraft (the LQR method of fig. 5 is what is used in the LQR feedback block of fig. 1, the result of which goes to outputs block of flight control system in fig. 1). Shue et al. does not teach, either alone or in combination with the prior art of record an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture; wherein the initialization command logic selectively activates the lateral control architecture for controlling the lateral motion of the aircraft and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft; and wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control speed variations of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

Claims 1-20 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

Electronic Patent Application Fee Transmittal

Application Number:				
Filing Date:				
Title of Invention:	Flight Control Laws for Constant Vector Flat Turns			
First Named Inventor/Applicant Name:	Kevin Thomas Christensen			
Filer:	James Edward Walton			
Attorney Docket Number:	0837RF-H793-C			
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility application filing	1011	1	390	390
Utility Search Fee	1111	1	620	620
Utility Examination Fee	1311	1	250	250
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1260

Electronic Acknowledgement Receipt

EFS ID:	14440424
Application Number:	13711234
International Application Number:	
Confirmation Number:	1159
Title of Invention:	Flight Control Laws for Constant Vector Flat Turns
First Named Inventor/Applicant Name:	Kevin Thomas Christensen
Customer Number:	38441
Filer:	James Edward Walton
Filer Authorized By:	
Attorney Docket Number:	0837RF-H793-C
Receipt Date:	11-DEC-2012
Filing Date:	
Time Stamp:	17:05:27
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$ 1260
RAM confirmation Number	4296
Deposit Account	502806
Authorized User	WALTON, JAMES E

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	aia0014.pdf	2271949	no	6
			426ebf32dc717c18e7e6ae0f2398d282178852fb		
Warnings:					
Information:					
2		ContinuationApplication20121211.pdf	2257629	yes	38
			038393145b2e3487e131bd150f9939a260d696eb		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Miscellaneous Incoming Letter		1	2	
	Specification		3	16	
	Claims		17	20	
	Abstract		21	21	
	Drawings-only black and white line drawings		22	30	
	Oath or Declaration filed		31	31	
	Oath or Declaration filed		32	32	
	Oath or Declaration filed		33	33	
	Transmittal Letter		34	35	
	Information Disclosure Statement (IDS) Form (SB08)		36	38	
Warnings:					
Information:					
3	Foreign Reference	WO2007018572A2.pdf	2246191	no	50
			c8e6a2f95e399f4d5e8f014d651fcf0a212f106		
Warnings:					
Information:					
4	Non Patent Literature	WOISA20110826.pdf	617328	no	7
			4f49860ebe9122216262e6571bd3ecd6a56df0e		

Warnings:					
Information:					
5	Non Patent Literature	NOA20120808.pdf	527832 bb9edef1eed4d587cdac68b9d3d653234e dc09fb	no	11
Warnings:					
Information:					
6	Fee Worksheet (SB06)	fee-info.pdf	32764 2505eb9cd99fd5cc0315c0c89e0d724d713 cf3ff	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			7953693		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0837RF-H793-C
		Application Number	
Title of Invention	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
--

Inventor Information:

Inventor 1					Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	KEVIN	THOMAS	CHRISTENSEN			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	Plano	State/Province	TX	Country of Residence ⁱ	US	
Mailing Address of Inventor:						
Address 1		3905 Branchwood Drive				
Address 2						
City	Plano	State/Province	TX			
Postal Code	75093	Country ⁱ	US			
Inventor 2					Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	SHYHPYNG	JACK	SHUE			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	Grapevine	State/Province	TX	Country of Residence ⁱ	US	
Mailing Address of Inventor:						
Address 1		2809 Woodland Hills Drive				
Address 2						
City	Grapevine	State/Province	TX			
Postal Code	76051	Country ⁱ	US			
Inventor 3					Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	TROY	SHELDON	CAUDILL			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						

Application Data Sheet 37 CFR 1.76		Attorney Docket Number		0837RF-H793-C	
		Application Number			
Title of Invention		FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS			
City	Burleson	State/Province	TX	Country of Residence i	US
Mailing Address of Inventor:					
Address 1		6195 Oak Hollow Drive			
Address 2					
City	Burleson	State/Province	TX		
Postal Code	76028	Country i	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.					Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	38441		
Email Address	jim@waltonpllc.com	Add Email	Remove Email

Application Information:

Title of the Invention	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS				
Attorney Docket Number	0837RF-H793-C	Small Entity Status Claimed ☐			
Application Type	Nonprovisional				
Subject Matter	Utility				
Suggested Class (if any)		Sub Class (if any)			
Suggested Technology Center (if any)					
Total Number of Drawing Sheets (if any)	9	Suggested Figure for Publication (if any)	1		

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.
--

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0837RF-H793-C
		Application Number	
Title of Invention	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS		
Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	38441		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.					
Prior Application Status	Patented		Remove		
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
	Continuation of	13391522	2012-02-21	8332082	2012-12-11
Prior Application Status	Pending		Remove		
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)		
13391522	a 371 of international	PCT/US11/30498	2011-03-30		
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.					Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).			
			Remove
Application Number	Country i	Filing Date (YYYY-MM-DD)	Priority Claimed
			☒ Yes ☐ No
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			Add

Authorization to Permit Access:

☐ Authorization to Permit Access to the Instant Application by the Participating Offices

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0837RF-H793-C
		Application Number	
Title of Invention	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS		

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.			
Applicant 1			
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.			
Remove			
☒ Assignee	☐ Legal Representative under 35 U.S.C. 117		
☐ Person to whom the inventor is obligated to assign.	☐ Person who shows sufficient proprietary interest		
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:			
Name of the Deceased or Legally Incapacitated Inventor :			
If the Assignee is an Organization check here. ☒			
Organization Name	BELL HELICOPTER TEXTRON INC.		
Mailing Address Information:			
Address 1	P.O. Box 482		
Address 2			
City	Fort Worth	State/Province	TX
Country ⁱ	US	Postal Code	76101
Phone Number		Fax Number	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0837RF-H793-C
		Application Number	
Title of Invention	FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS		

Email Address	
---------------	--

Additional Applicant Data may be generated within this form by selecting the Add button.

Add

Signature:

Remove

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications					
Signature	/jamesewaltonpat/			Date (YYYY-MM-DD)	2012-12-11
First Name	James	Last Name	Walton	Registration Number	47245
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 0837RF-H793-C

In Re Application of:

KEVIN THOMAS CHRISTENSEN, ET AL.

Serial No: TO BE ASSIGNED

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For: FLIGHT CONTROL LAWS FOR
CONSTANT VECTOR FLAT TURNS

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Respectfully submitted,

12/11/12
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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that we, Kevin Thomas Christensen, residing in the city of Plano, Texas 75093; Shyhyng Jack Shue, residing in the city of Grapevine, Texas 76051; and, Troy Sheldon Caudill, residing in the city of Burleson, Texas 76028, all being U.S. citizens, have invented a new and useful

FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

of which the following is a specification.

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BACKGROUND

1. Field of the Invention

[0001] The present invention relates generally to flight control systems, and more particularly, to a flight control system having flight control laws which enable precise aircraft maneuvering relative to the ground.

2. Description of Related Art

[0002] Aircraft which can hover and fly at low speeds include rotorcraft, such as helicopters and tilt rotors, and jump jets, like the AV-8B Harrier and F-35B Lightning II. These aircraft can spend a large portion of their mission maneuvering relative to the ground. Sometimes, this maneuvering must be conducted in confined spaces around external hazards such as buildings, trees, towers, and power lines.

[0003] For traditional flight control systems, ground-referenced maneuvering (GRM) requires the pilot to make constant control inputs in multiple axes in order to counter disturbances caused by wind, as well as to remove the natural coupled response of the aircraft. The pilot workload during such maneuvers can become quite high since the pilot must sense un-commanded aircraft motions and then put in the appropriate control input to eliminate the disturbance. In a worst-case scenario, a pilot might be required to fly GRM in a degraded visual environment. With the lack of visual cues to detect off-axis motion, the pilot might accidentally fly into an external hazard while maneuvering in a confined space.

[0004] Traditional flight control law designs do not provide the pilot with an easy way to control aircraft crab angle during GRM. Crab angle is defined as the angle between the aircraft's heading and its actual ground path. With these prior designs, adjusting crab angle while maintaining ground track took considerable pilot concentration, since the pilot had to coordinate inputs to both the lateral and directional controllers.

[0005] Although pilots generally seek to minimize crab angle during GRM, some mission tasks may call for flat yawing turns while maintaining a constant vector across

the ground. For example, on a steep approach, the pilot may need to fly with a crab angle so he or she can see the landing zone. Additionally, the pilot may want to quickly transition out of rearward or sideward flight while continuing along the same ground track. In a final example, the pilot may want to acquire and track a point on the ground without having to fly directly towards it. With prior flight control designs, such maneuvers required extraordinary pilot skill to coordinate the aircraft's motions in multiple control axes.

[0006] Although the foregoing developments represent great strides in the area of flight control laws, many shortcomings remain.

DESCRIPTION OF THE DRAWINGS

[0007] The novel features believed characteristic of the embodiments of the present application are set forth in the appended claims. However, the embodiments themselves, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a flight envelope with control law modes designed to enable ground reference maneuvers;

Figure 2 is a schematic of an aircraft utilizing a control system according to the preferred embodiment of the present invention;

Figure 3 is a set of plots comprising measured flight data of the aircraft of Fig. 2 while performing constant vector flat turns;

Figure 4 is a schematic view of the aircraft of Fig. 2 changing flight heading from sideward flight to forward flight;

Figure 5 is a schematic view of the aircraft of Fig. 2 changing flight heading from forward flight to sideward flight;

Figure 6 is a schematic view of the control system architecture for a set of longitudinal control laws;

Figure 7 is a schematic view of the control system architecture for a set of lateral control laws;

Figure 8 is a schematic view of the control system architecture for directional control laws;

Figure 9 is a schematic view of the control law logic for the control system; and

Figure 10 is a schematic view a control law flow chart for the control system.

[0008] While the control system of the present application is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular embodiment disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the process of the present application as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009] Illustrative embodiments of the system and method are provided below. It will of course be appreciated that in the development of any actual embodiment, numerous implementation-specific decisions will be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0010] This invention will enable seamless and transient free GRM. More specifically this invention will enable a pilot to use the directional controller to command flat yawing

turns at low groundspeeds, while maintaining a constant vector across the ground. The seamless integration of this design requires no manual cockpit switches to select a Constant Vector Flat Turn (CVFT) mode. Instead, the control laws will automatically adjust pitch and roll attitude to keep the aircraft moving in the same direction at a constant speed whenever the pilot inputs a directional command at low speed.

[0011] The control system of the present application enables seamless and transient free GRM without the need for manual cockpit switches. The control system utilizes relative groundspeed difference to automatically control pitch and roll attitudes so that the aircraft will maintain a constant vector during a low speed flat turn. The control system also allows the pilot to complete a CVFT with minimal workload since the ground vector will automatically be maintained by the control laws without the pilot having to use cockpit switches to change modes.

[0012] Referring now to the drawings, Figure 1 shows a representative flight envelope 101 with a plurality of control law modes designed to enable GRM. Flight envelope 101 comprises a region 103 depicting the CVFT region, wherein the CVFT region is preferably from 10 to 35 knots groundspeed in any direction relative to the aircraft's body axis. The lower bound of region 103 is set by the Hover Hold and Translational Rate Command (TRC) region 105. The upper bound of region 103 is set by the aircraft's sideward and rearward flight airspeed limits.

[0013] Figure 2 is a schematic of an aircraft 201 utilizing a control system according to the preferred embodiment of the present invention. Figure 2 shows aircraft 201 in forward flight within region 103. Directional inputs turn aircraft 201 in a complete 360 degree yaw movement R1, stopping every 90 degrees, and without changing the speed and flight heading of aircraft 201, as represented with arrow D1. In the preferred embodiment, the control system is utilized with rotary aircraft, i.e., a helicopter; however, it should be appreciated that the control system is easily and readily adaptable with control systems of different types of aircraft, both manned and unmanned.

[0014] Figure 2 depicts aircraft 201 traveling between 10 to 35 knots in a forward direction. As is shown, aircraft 201 preferably turns in a yaw direction R1 at

approximately 90 degrees relative to direction D1. Aircraft 201 continues to turn in direction R1 while maintaining a constant flight heading. It should be appreciated that the preferred control system is adapted to turn aircraft 201 at 90 degrees during each application; however, it should be appreciated that alternative embodiments could easily include a control system adapted to turn the aircraft at different angles, e.g., at 30 degrees in lieu of or in addition to 90 degrees. It should also be understood that although shown turning in a clockwise direction, the control system can also turn the aircraft in a counterclockwise movement.

[0015] Figure 2 provides an exemplary depiction of aircraft 201 turning 360 degrees while maintaining forward flight. Step 1 shows aircraft 201 traveling in a constant forward flight, as depicted with arrow D1, between 10 and 35 knots. Step 2 depicts application of the control system, namely, the pilot utilizes the control system to rotate aircraft 201 in the clockwise direction approximately 90 degrees, as indicated by arrow R1. Step 2 shows aircraft 201 traveling in forward flight while the fuselage faces 90 degrees relative to the directional movement. Steps 3-5 provide further illustration of the process being repeated. In particular, each time the control system is utilized, aircraft 201 rotates 90 degrees while maintaining a constant forward heading.

[0016] Referring now to Figure 3 in the drawings, measured flight data 301 of aircraft 201 is shown during a 360 degree CVFT. A plot 303 provides measured data representing the turning movement R1 of aircraft 201 during the 360 degree turn. A plot 305 provides measured data representing the groundspeed of aircraft 201 during the 360 degree turn. Plot 305 shows aircraft 201 initially starting at 20 knots forward groundspeed during the entire 360 degree CVFT. Plot 305 shows that aircraft 201 holds a relatively steady groundspeed during the 360 degree CVFT. A plot 307 provides measured data representing the ground track of aircraft 201 during the 360 degree CVFT. The forward groundspeed plotted on a plot 309 essentially depicts a cosine curve during the turn, while the sideward groundspeed plotted on a plot 311 shows a sine curve.

[0017] Referring now to Figure 4 in the drawings, a schematic view of aircraft 201 is shown changing flight heading from sideward flight to forward flight. In the exemplary embodiment, the CVFT control system is utilized such that aircraft 201 changes heading from a forward groundspeed V_x of about 0 knots and a sideward groundspeed between 10-35 knots to a forward groundspeed between 10-35 knots and a sideward groundspeed about 0 knots. Step 1 of Figure 4 shows aircraft 401 during hover, while a step 2 shows aircraft 401 traveling in a sideward groundspeed between 10-35 knots, as depicted with arrow D2. In step 2, a right lateral control stick (not shown) is utilized to generate a left sideward heading. Thereafter, a right 90 degree petal turn is applied to rotate aircraft 201 in a forward heading with a petal 203. In the preferred embodiment, petal 203 is a petal manipulated with the pilot's foot; however, it should be appreciated that other forms of devices, i.e, a hand switch could be utilized in lieu of or in addition to petal 203. For purposes of this invention, a lateral controller, longitudinal controller, and directional controller are characterized as petal 203 or similarly suited devices. Step 3 depicts application of the CVFT control system, wherein aircraft 201 turns 90 degrees for changing the heading of aircraft 201.

[0018] Referring now to Figure 5 in the drawings, an alternative application of the CVFT control system is shown. In the exemplary embodiment, the CVFT control system is utilized to turn aircraft 201 from a forward groundspeed V_x between 10-35 knots and a sideward groundspeed of about 0 knots to a sideward groundspeed between 10-35 knots and a forward groundspeed about 0 knots. Step 1 shows aircraft 201 during hover, while a step 2 shows aircraft 201 traveling in a forward heading having a groundspeed between 10-35 knots, as depicted with arrow D3. In step 2, a forward longitudinal stick is utilized to generate forward flight. Thereafter, a left 90 degree petal turn is applied to rotate aircraft 201 such that the forward flight of aircraft 201 changes to a sideward flight heading.

[0019] Those skilled in the art will understand that the methods for aircraft guidance disclosed in this invention can be applied to any combination of the following: (1) full authority fly-by-wire flight control systems, as well as partial authority mechanical systems; (2) traditional cockpit layouts with a center stick for longitudinal and lateral

control, pedals for directional control, and a collective stick for vertical control, as well as more advanced designs which combine multiple control axes into a center or side stick controller; and, (3) any aircraft capable of GRM, including both rotorcraft and jump jets.

[0020] The key to enabling seamless and transient free GRM lies in the advanced control law architecture of the CVFT control system as shown in Figures 6 to 8. Figure 6 shows architecture 601 of the CVFT control system operably associated with one or more longitudinal control laws, Figure 7 shows architecture 701 of the CVFT control system operably associated with one or more lateral control laws, and Figure 8 shows architecture 801 of the CVFT control system operably associated with one or more directional control laws according to the preferred embodiment of the invention.

[0021] Referring now to Figure 6 in the drawings, architecture 601 includes one or more aircraft sensors 603 operably associated with the control laws to accomplish GRM. Aircraft sensors 603 can include: an inertial Navigation System (attitudes, attitude rates, and translational accelerations); a Global Positioning System (ground-referenced speeds and positions); an Air Data Computer (airspeed and barometric altitude); and, a Radar or Laser Altimeter (above ground level (AGL) altitude). An aircraft model can be obtained from aerodynamics data and a group of linear models can be developed based on its airspeed from aircraft sensors 603. These linear models include both lateral and longitudinal equations of motion. Since the aircraft model matrices are large and contain coupling terms of lateral and longitudinal motions within the matrices, it is difficult to determine the best performance control gains for all at the same time. In order to overcome these issues, the linear model of aircraft performance is decoupled first. After the aircraft model is decoupled to lateral and longitudinal equations of motion, the effect of coupling terms between lateral and longitudinal motions can be reduced to minimum, thus stabilizing the system.

[0022] In the preferred embodiment, architecture 601 preferably comprises of a longitudinal control law for forward speed, represented as block 605 "Long_SPD"; a longitudinal control law for pitch angle, represented as block 607 "Long_ATT"; and, a longitudinal control law for pitch rate, represented as block 609 "Long_RATE".

Architecture 601 is further provided with initialization logic 611 adapted for determining which loop is active in each axis based on flight conditions and pilot control inputs. Logic 611 will also re-initializes inactive loops in order to eliminate control jumps when switching between the loops to provide seamless and transient free mode changes.

[0023] Architecture 601 further includes a longitudinal command 613 generated in the control laws by referencing the pilot's cockpit control input in each axis. The input to the control laws is the difference between the controller's present position and the centered, no force position, which is also referred to as the "detent" position. The control commands can also be generated by a beep switch located in the cockpit to command small and precise changes in aircraft state. The control laws process these control inputs to generate the appropriate aircraft response commands. These commands are then sent out to the control law guidance blocks to maneuver the aircraft. The control law outputs are routed to an actuator 615 for each dynamic axis. For a conventional helicopter, the control laws send control signals to the following actuators: longitudinal axis – main rotor longitudinal swashplate angle; lateral axis – main rotor lateral swashplate angle; vertical axis – main rotor collective pitch; and, directional axis – tail rotor collective pitch.

[0024] Since pitch rate is the fastest longitudinal state, Long_RATE 609 is the inner loop of the longitudinal control laws. Next, the Long_ATT 607 loop feeds the Long_RATE control law 609 loop to control pitch attitude. Finally, the Long_SPD control law 605 loop feeds the Long_ATT 607 loop to control forward speed.

[0025] When flying with the longitudinal controller in detent outside of the Hover Hold / TRC region 105, depicted in Figure 1, the Long_SPD 605 loop will be active. At lower speeds, this loop will hold constant forward groundspeed, while at higher speeds, airspeed will be held. Once the pilot moves the longitudinal controller out of detent, the control laws can command either pitch attitude (Long_ATT 607) or pitch rate (Long_RATE 609).

[0026] Referring now to Figure 7 in the drawings, architecture 701 comprises one or more lateral control laws operably associated with sensors 603, logic 611, lateral

commands 702, and actuators 615. The lateral control laws include: a lateral control of roll rate, represented as block 703 “Lat_RATE”; a lateral control of the roll attitude, represented as block 705 “Lat_ATT”; a lateral control of sideward groundspeed, represented as block 707 “Lat_SPD”; a lateral control of the crab angle, represented as block 709 “Lat_CRAB”; and, lateral control of heading, represented as block 711 “Lat_HDG”.

[0027] Similar to the longitudinal axis, Lat_RATE 703 is the inner loop of the lateral control laws and the Lat_ATT 705 loop feeds the Lat_RATE 703 loop to control roll attitude. The Lat_ATT 705 loop can be fed by one of three loops, Lat_SPD 707, Lat_CRAB 709, or Lat_HDG 711.

[0028] The crab angle used in the Lat_CRAB 709 loop is computed in the control laws using the following equation:

$$\eta = \tan^{-1}\left(\frac{V_y}{V_x}\right) \quad (1)$$

[0029] where η is the crab angle, V_y is the sideward groundspeed with right positive, and V_x is the forward groundspeed. To avoid a singularity in Equation 1, V_x is limited to be above the Hover Hold / TRC region 103.

[0030] When operating in the Ground-Coordinated Banked Turn (GCBT) envelope as shown by region 107 in Figure 1, if both the lateral and directional controllers are in detent, lateral control law logic will hold crab angle through the Lat_CRAB 709 loop. If operating in the CVFT envelope, but not in the GCBT envelope, and the lateral and directional controllers are in detent, the control logic will hold sideward groundspeed constant with the Lat_SPD 707 loop. When operating at higher airspeeds with lateral and directional controllers in detent, the control logic will hold heading constant with the Lat_HDG 711 loop. When the pilot moves the lateral controller out of detent in any of these cases, the control laws can command either roll attitude (Lat_ATT 705) or roll rate (Lat_RATE 703).

[0031] Referring now to Figure 8 in the drawings, architecture 801 comprises one or more directional control laws operably associated with sensors 603, logic 611, commands 613, and actuators 615. The directional control laws include: directional control of yaw rate, represented as block 803 “Dir_RATE”; directional control of heading, represented as block 805 “Dir_HDG”; and, directional turn coordination, represented as block 807 “Dir_TC”

[0032] Since yaw rate is the fastest directional state, Dir_RATE 803 is the inner loop of the directional control laws. This loop is fed by the Dir_HDG 805 loop to control aircraft heading at lower speeds. Unlike traditional control law designs, this invention includes an additional loop, parallel to the Dir_HDG 805 loop, to feed the Dir_RATE 803 inner loop. The Dir_TC 807 loop is used to coordinate banked turns throughout the flight envelope.

[0033] In the GCBT envelope 107 shown in Figure 1, the Dir_TC 807 loop will control crab angle during banked turns. With no directional input, the Dir_TC 807 loop will hold crab angle at zero. Any directional control inputs during a GCBT will result in a change in crab angle in the appropriate direction. Additionally, if the aircraft is in the GCBT envelope, but above the CVFT envelope, directional controller inputs will command changes in crab angle through the Dir_TC 807 loop even in non-turning flight. In this case, once the directional controller is returned to detent, heading hold will be re-engaged (Dir_HDG 805 loop) and the crab angle will be held through the Lat_CRAB 709 loop.

[0034] When in the BCBT envelope, the Dir_TC 807 loop will automatically adjust yaw rate based on actual bank angle, true airspeed, and lateral acceleration in order to keep the slip ball centered. Any directional controller inputs in the BCBT envelope will command a change in lateral acceleration, which will subsequently result in sideslip away from the pedal input. Pedal inputs will also result in a slight roll in the direction of the input to provide lateral stability.

[0035] In the absence of lateral or directional control inputs while operating in either the GCBT or CVFT envelopes, the directional axis will hold heading through the

Dir_HDG 805 loop. If the pilot moves the directional controller out of detent in the CVFT envelope with both the lateral and longitudinal controllers in detent, the directional control laws will command a yaw rate through the Dir_RATE 803 loop. In this case, the control laws will maintain a constant ground vector by using the Long_SPD 605 and Lat_SPD 707 loops.

[0036] During the CVFT, when the directional controller is first moved out of detent, the control laws will capture the aircraft's current groundspeed in the earth axis coordinate system. The control laws keep track of the difference between the aircraft's actual groundspeed and the captured groundspeed. This relative groundspeed difference is converted from the earth axis to the aircraft's body axis using the following equations:

$$\Delta V_x = \Delta V_{north} \cdot \cos \psi + \Delta V_{east} \cdot \sin \psi \quad (2)$$

$$\Delta V_y = \Delta V_{east} \cdot \cos \psi - \Delta V_{north} \cdot \sin \psi \quad (3)$$

[0037] where ΔV_x is the groundspeed difference in the body axis forward direction, ΔV_y is the groundspeed difference in the body axis sideward direction with right positive, ΔV_{north} is the groundspeed difference in the earth axis north direction, ΔV_{east} is the groundspeed difference in the earth axis east direction, and ψ is the aircraft heading. The values for ΔV_x and ΔV_y are then used in the Long_SPD 605 and Lat_SPD 707 blocks respectively to command the pitch and roll attitudes needed to minimize the relative groundspeed difference during the flat turn.

[0038] Referring now to Figure 9 in the drawings, control law logic 901 for the CVPT mode is shown. Control law logic 901 comprises one or more of latch 903, latch 905, and latch 907 adapted to control when a mode is turned on or off. If the reset conditions are met, then the mode will always be off. If the reset conditions are not met, then the mode will be latched on when the set conditions are met. The CVPT mode will be reset whenever lateral speed hold, depicted as block 909 "Lat_SPD_ON" or a longitudinal

speed hold, depicted as block 911 "Long_SPD_ON" are not on and will be set when the directional controller is out of detent.

[0039] Both longitudinal latch 905 and lateral speed hold latch 907 will be reset when their respective controller is out of detent. Additionally, the lateral speed hold latch 907 will be reset when the banked turn (Bank_Turn_ON) or crab hold (Crab_ON) modes are on, or if forward speed exceeds the CVPT threshold (typically around 35 KGS). The longitudinal and lateral speed hold latches will be set when their respective acceleration falls below the acceleration threshold (typically around 2 ft/sec²).

[0040] Referring now to Figure 10 in the drawings, a control law flow chart 1001 for a CVFT is presented. When the directional controller is initially moved out of detent, the CVPT mode will be engaged. The longitudinal and lateral speed hold blocks (Long_SPD 605 and Lat_SPD 707) will be reinitialized to feedback the relative groundspeed differences calculated in equations 2 and 3. Once the directional controller is returned to detent following the CVFT, directional control laws will hold heading by re-engaging the Dir_HDG 805 loop. The longitudinal and lateral axes will continue to hold a constant ground vector until the pilot commands a change by moving either the longitudinal or lateral controller out of detent. This design enables the pilot to command and hold any crab angle around the 360 degree circle, while the aircraft continues to move across the ground on a constant vector. As shown, when the pedal stops, if the crab angle equals 0 degrees, then aircraft 201 travels in pure forward flight; if the crab angle is 90 degrees, aircraft 201 travels in pure right side flight; if the crab angle is 180 degrees, then aircraft 201 travels in pure aft flight; and, if the crab angle is 270 degrees, then aircraft 201 travels in pure left sideward flight.

[0041] The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. It is therefore evident that the particular embodiments disclosed above may be altered or modified, and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the description. It is apparent that an

invention with significant advantages has been described and illustrated. Although the present invention is shown in a limited number of forms, it is not limited to just these forms, but is amenable to various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. A control system for an aircraft, comprising:
a lateral control architecture configured to control lateral motion of the aircraft;
and
a longitudinal control architecture configured to control longitudinal motion of the aircraft;
wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.
2. The control system of claim 1, wherein the control system is operably associated with a directional controller manually manipulated by a pilot.
3. The control system of claim 2, further comprising:
a directional control architecture, having:
a directional heading control loop;
a directional turn coordination control loop; and
a directional yaw rate control loop.
4. The control system of claim 3, further comprising:
a directional control latch in data communication with the directional control architecture;
wherein, as the directional controller is moved out of a detent position, the directional control latch activates a constant vector flat turn motion.
5. The control system of claim 1, the lateral control architecture comprising:
a lateral sideward groundspeed control loop;
a lateral roll attitude control loop; and
a lateral roll rate control loop.

6. The control system of claim 5, further comprising:
a lateral controller carried by the aircraft, the lateral controller being manipulated by a pilot controlling the aircraft, the lateral controller creating a lateral command in data communication with the lateral sideward groundspeed control loop, the lateral roll attitude control loop, and the lateral roll rate control loop.
7. The control system of claim 6, further comprising:
a lateral control hatch in data communication with the control system;
wherein, as the lateral controller is moved out of a detent position, the lateral control hatch resets a lateral speed hold.
8. The control system of claim 1, the longitudinal control architecture comprising:
a longitudinal forward speed control loop;
a longitudinal pitch angle control loop; and
a longitudinal pitch rate control loop.
9. The control system of claim 8, the longitudinal control architecture further comprising:
a longitudinal controller carried by the aircraft, the longitudinal controller being manipulated by a pilot controlling the aircraft, the longitudinal controller creating a longitudinal command in data communication with the longitudinal forward speed control loop, the longitudinal pitch angle control loop, and the longitudinal pitch rate control loop.
10. The control system of claim 9, further comprising:
a longitudinal control hatch in data communication with the control system;
wherein, as the longitudinal controller is moved out of a detent position, the longitudinal control hatch resets a longitudinal speed hold.

11. A method, comprising:
 - sensing a directional movement of a aircraft;
 - determining lateral and longitudinal movements of the aircraft; and
 - selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface.
12. The method of claim 11, the method further comprising:
 - commanding the flat yaw movement with a directional controller manipulated by a pilot controlling the aircraft.
13. The method of claim 12, wherein controlling the flat yaw movement comprises:
 - communicating data through a directional heading control loop;
 - communicating data through a directional turn coordination control loop; and
 - communicating data through a directional yaw rate control loop.
14. The method of claim 12, further comprising:
 - activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position.
15. The method of claim 11, wherein determining lateral movements is achieved through the method comprising:
 - communicating lateral motion data through a lateral sideward groundspeed control loop;
 - communicating lateral motion data through a lateral roll attitude control loop; and
 - communicating lateral motion data through a lateral roll rate control loop.
16. The method of claim 11, further comprising:
 - controlling lateral movement with a lateral controller manipulated by a pilot controlling the aircraft.

17. The aircraft of claim 16, further comprising:
resetting a lateral speed hold with a lateral control hatch as the lateral controller is moved out of a detent position.
18. The method of claim 17, wherein controlling longitudinal movement includes the method comprising:
communicating longitudinal motion data through a longitudinal forward speed control loop;
communicating longitudinal motion data through a longitudinal pitch angle control loop; and
communicating longitudinal motion data through a longitudinal pitch rate control loop.
19. The aircraft of claim 11, further comprising:
controlling longitudinal movement with a longitudinal controller manipulated by a pilot controlling the aircraft.
20. The aircraft of claim 19, further comprising:
resetting a longitudinal speed hold with a longitudinal control hatch as the longitudinal controller is moved out of a detent position.

ABSTRACT

An aircraft and method to control flat yawing turns of the aircraft while maintaining a constant vector heading across a ground surface. The aircraft includes a control system in data communication with a model, a lateral control architecture, a longitudinal control architecture, and an initialization command logic. The model decouples the directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion. The lateral control architecture utilizes the lateral equation of motion to control the aircraft in the lateral direction, while the longitudinal control architecture utilizes the longitudinal equation of motion to control the aircraft in the longitudinal direction. The initialization command logic selectively activates the lateral control architecture and the longitudinal control architecture.

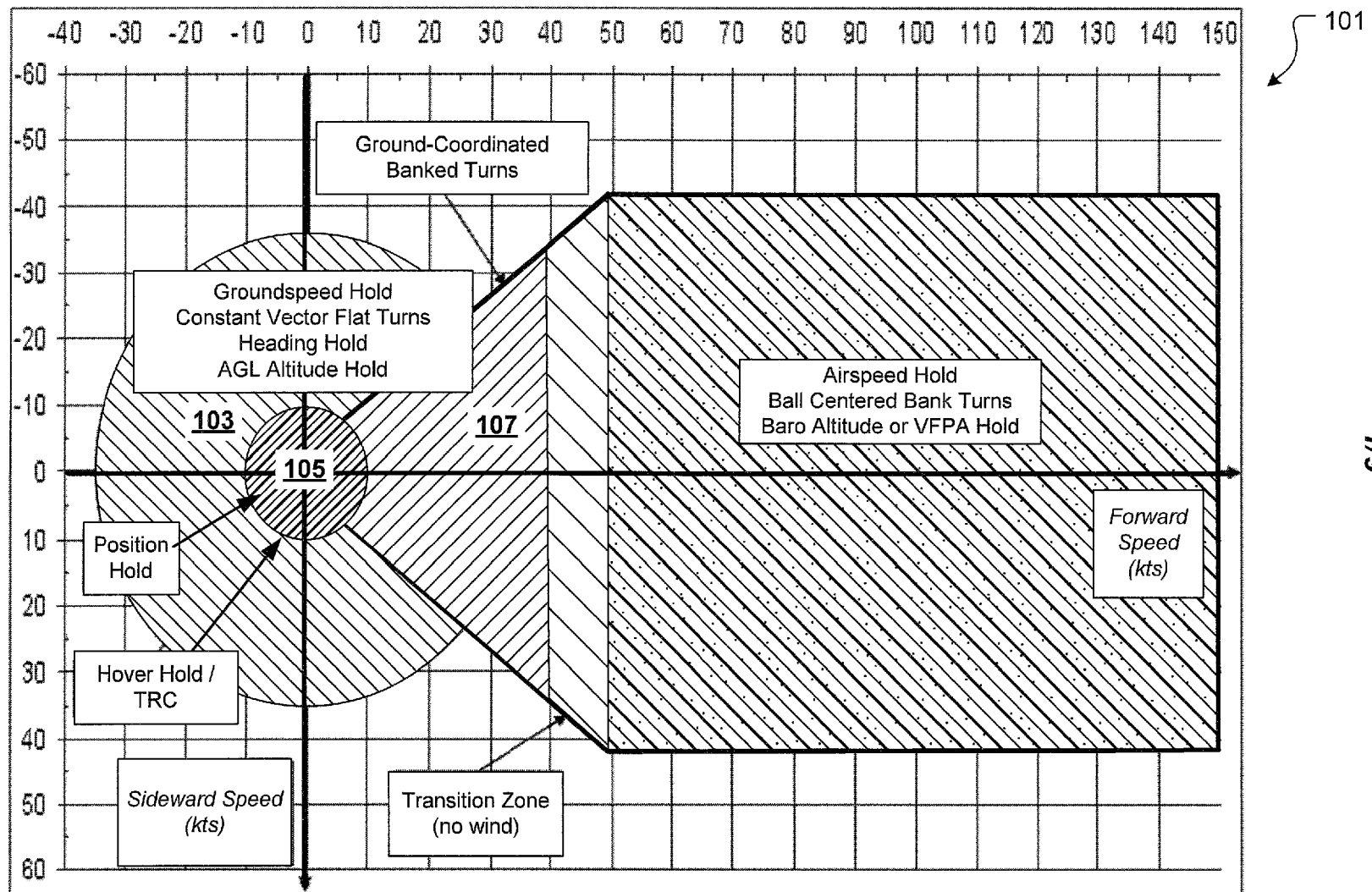


FIG. 1

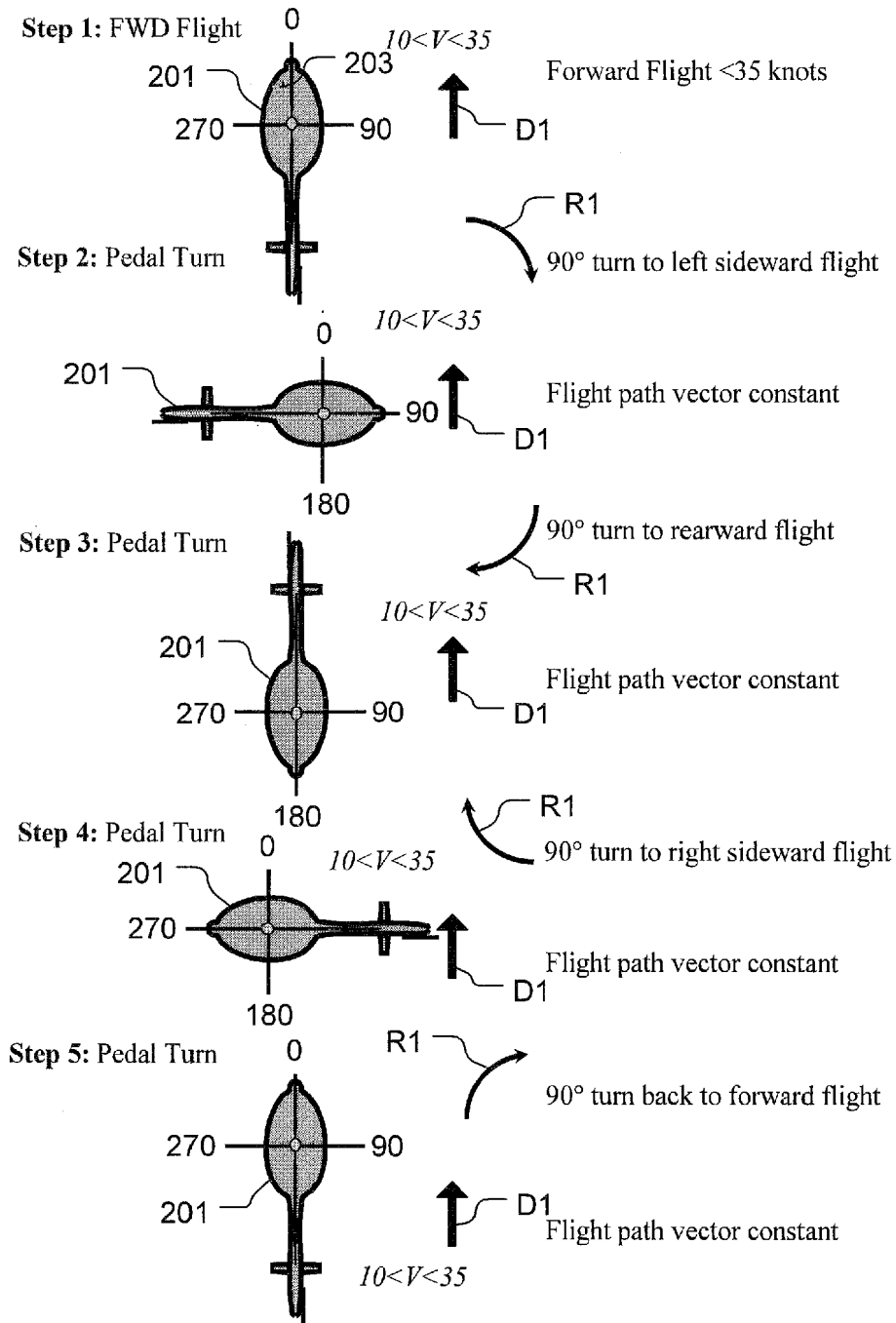


FIG. 2

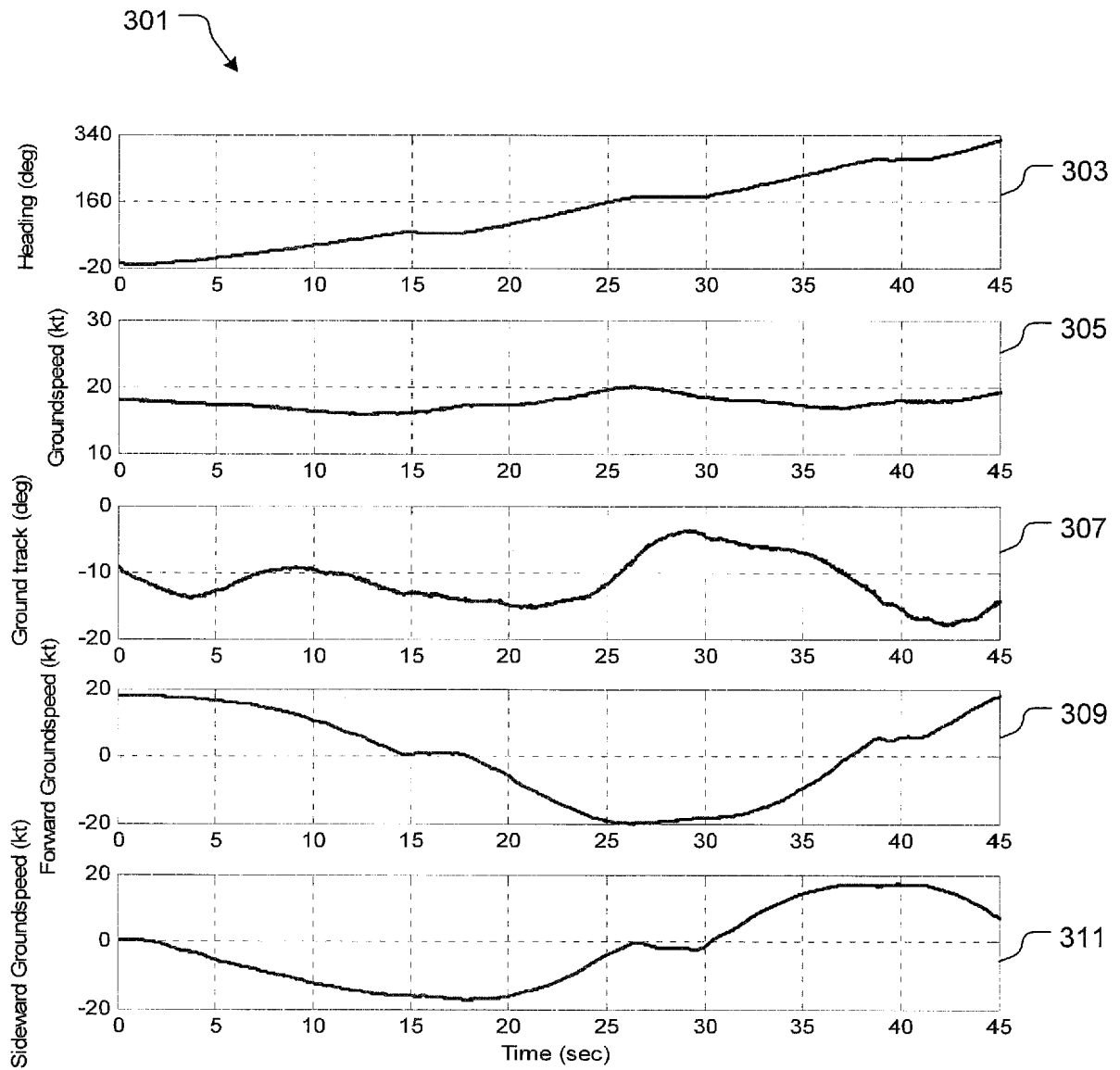


FIG. 3

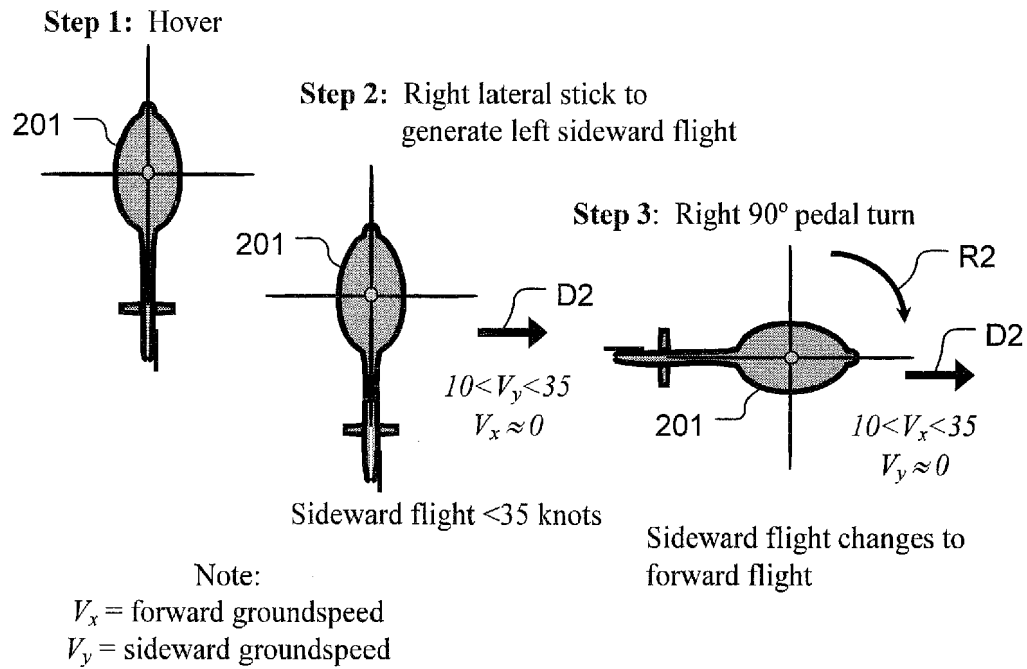


FIG. 4

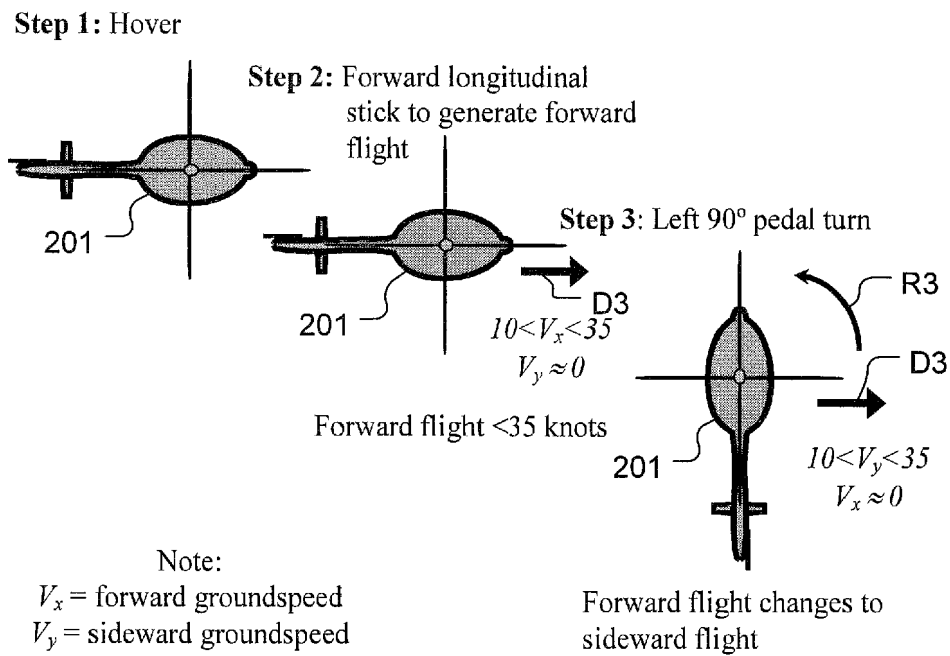
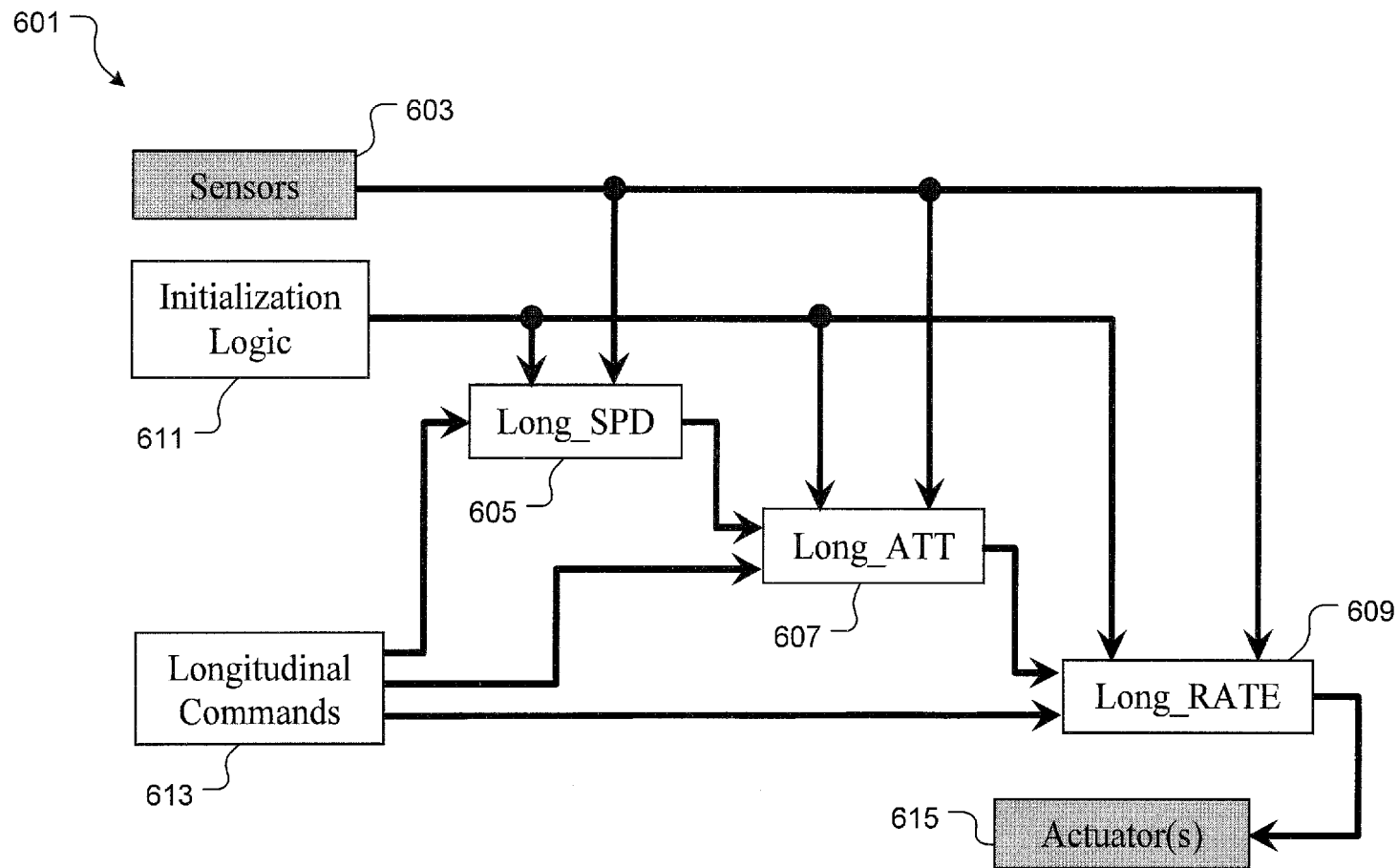


FIG. 5



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FIG. 6

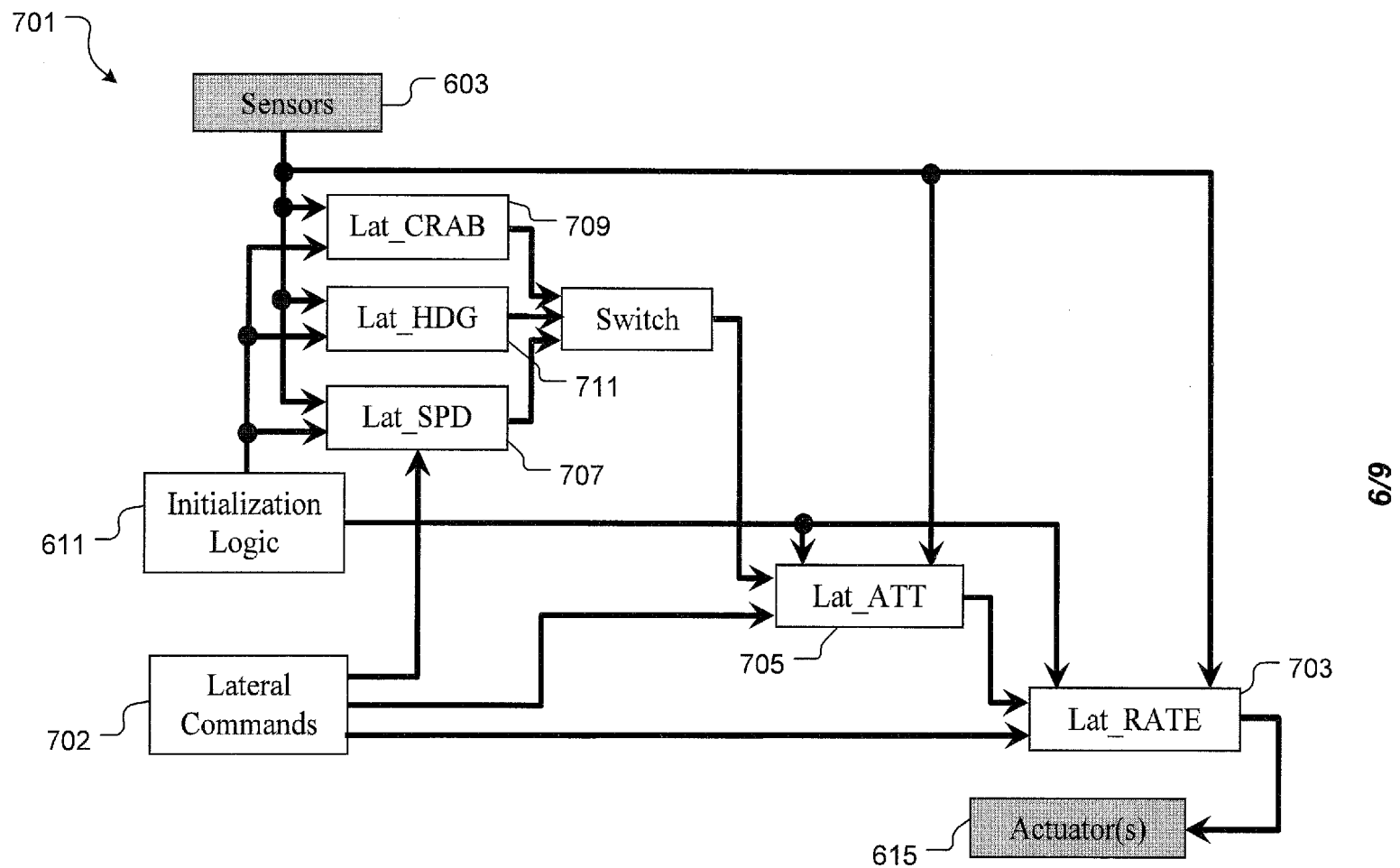
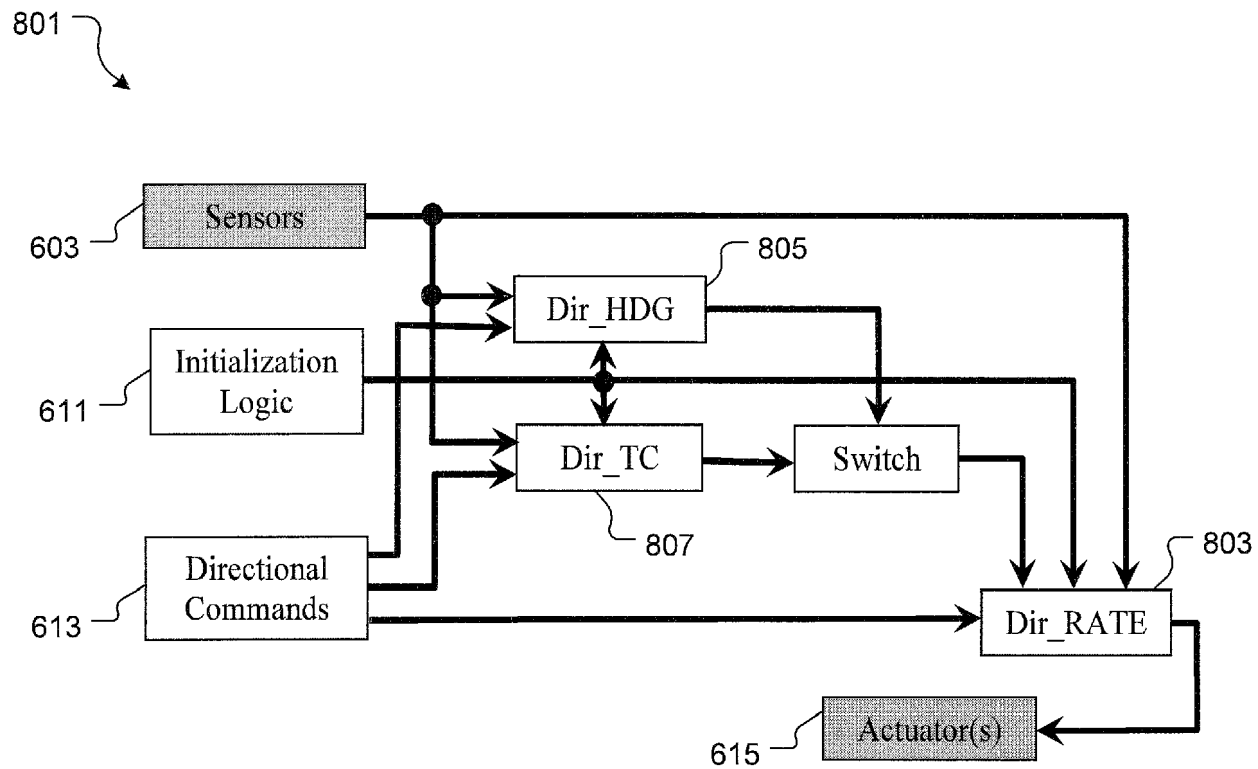


FIG. 7



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FIG. 8

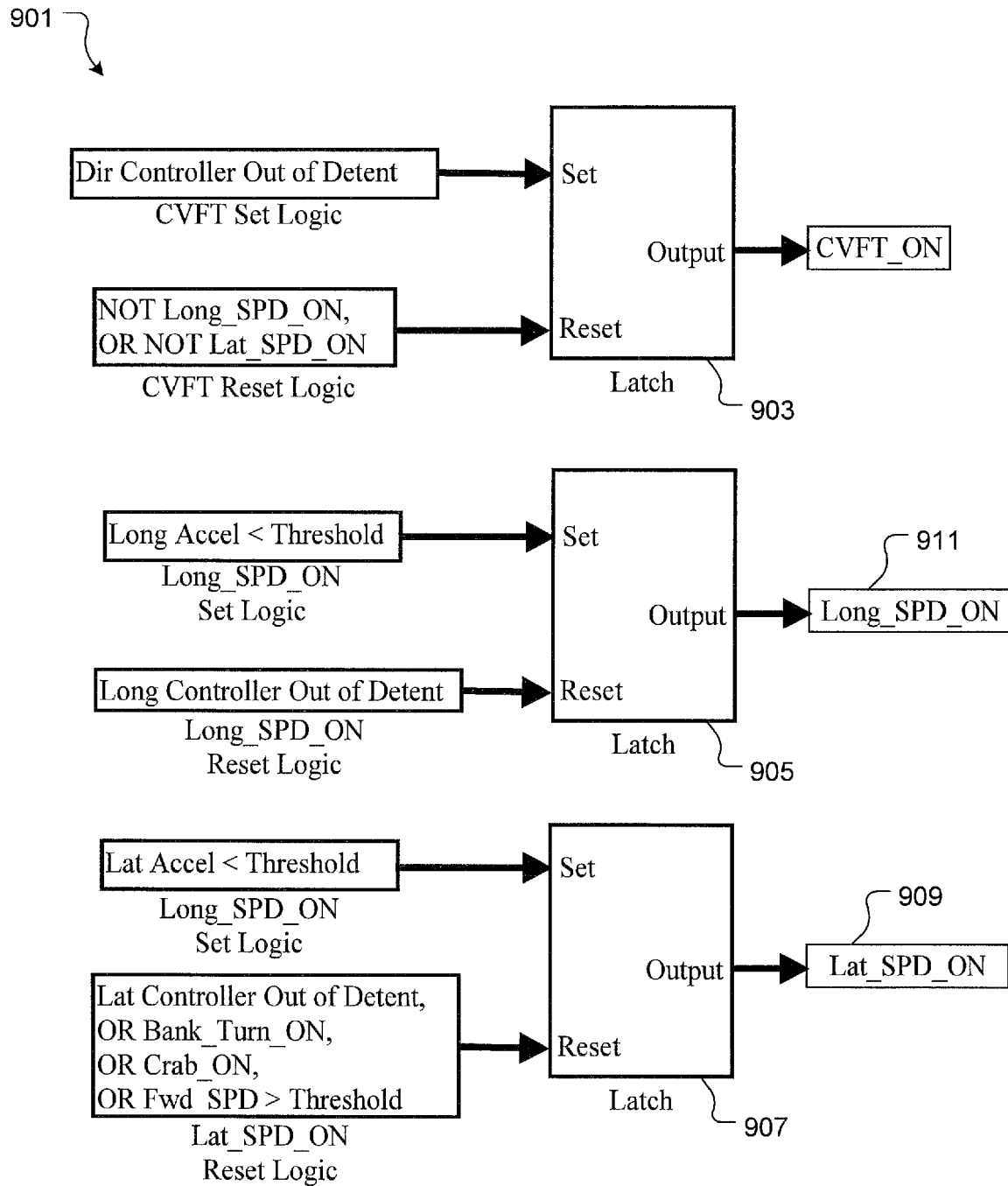
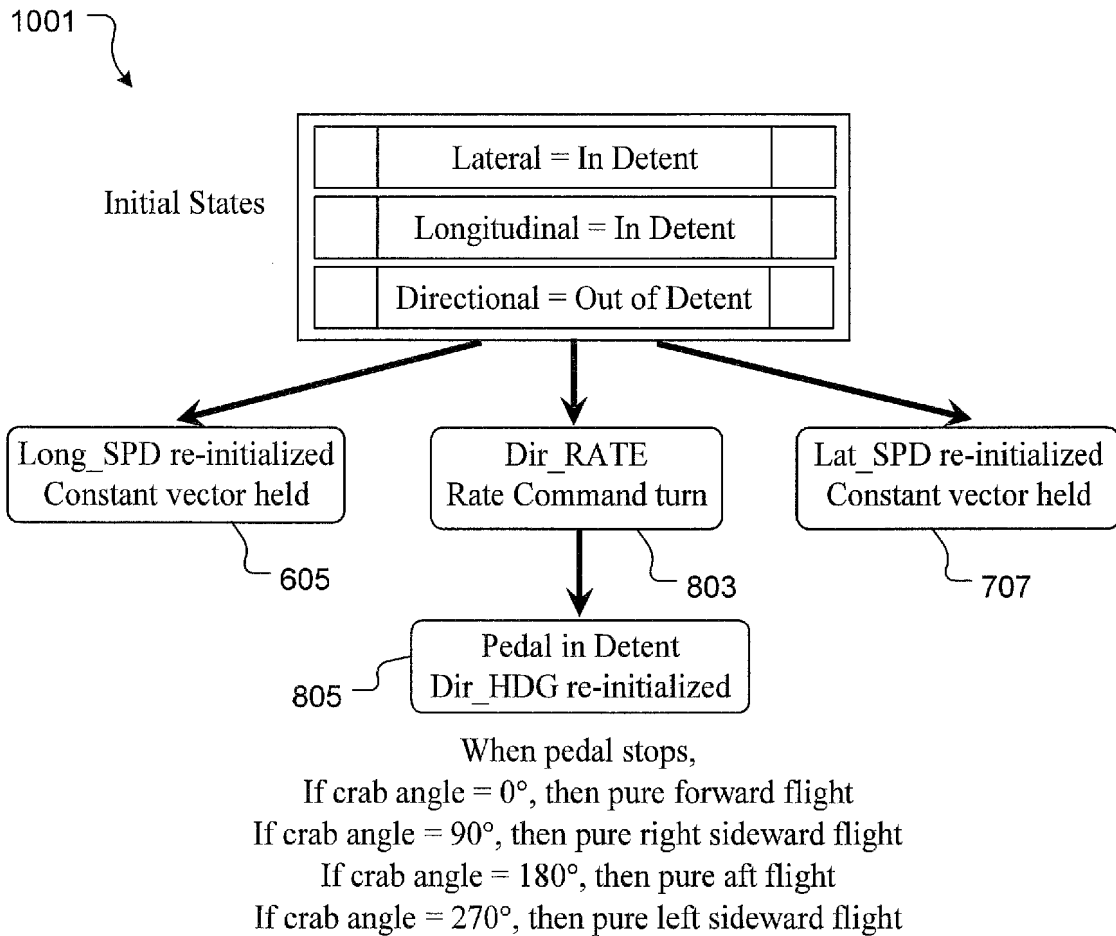


FIG. 9

**FIG. 10**