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Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME UNI

Date

12.07.17

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681
Applicant/Proprietor Bell Helicopter Textron Inc.	

Communication regarding the expiry of the time limit within which notice of opposition may be filed

You are hereby informed that on expiry of the nine-month time limit from the publication of the mention of the grant of European patent No. 2673681 no notice of opposition had reached the files.

The entry in the Register of European Patents will be automatically generated by the electronic data processing system.

For the Examining Division



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Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME UNI

Date

08.09.16

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681
Applicant/Proprietor Bell Helicopter Textron Inc.	

Transmission of the certificate for a European patent pursuant to Rule 74 EPC

The certificate for a European patent is herewith transmitted.

The European patent specification can be downloaded from the EPO publication server
<https://data.epo.org/publication-server/> (see OJ EPO 2005, 126).

Note:

A corrected title page of the European patent specification will be published, if the bibliographic data have been changed after completion of the technical preparations.

For the Examining Division



Questions about this communication ?

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Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME UNI

Date

11.08.16

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681
Applicant/Proprietor Bell Helicopter Textron Inc.	

Decision to grant a European patent pursuant to Article 97(1) EPC

Following examination of European patent application No. 11862189.5 a European patent with the title and the supporting documents indicated in the communication pursuant to Rule 71(3) EPC (EPO Form 2004C) or in the information (EPO Form 2004W, cf. Notice from the EPO dated 8 June 2015, OJ EPO 2015, A52) dated 05.07.16 is hereby granted in respect of the designated Contracting States.

Patent No. : 2673681
Date of filing : 30.03.11
Priority claimed : /

Designated Contracting States
and Proprietor(s) : AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI
LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Bell Helicopter Textron Inc.
P.O. Box 482
Fort Worth, TX 76101/US

This decision will take effect on the date on which the European Patent Bulletin mentions the grant (Art. 97(3) EPC).

The mention of the grant will be published in European Patent Bulletin 16/36 of 07.09.16.

Examining Division

Pöllmann H

Lalinde Araguas R

Vañó Gea J



ANMERKUNG ZUR ENTSCHEIDUNG ÜBER DIE ERTEILUNG
EINES EUROPÄISCHEN PATENTS (EPA Form 2006)

1. **EPA Informationsbroschüre "Nationales Recht zum EPÜ"**
Diese Broschüre enthält nützliche Informationen zu den formalen Erfordernissen und den Handlungen, die vor den Patentbehörden der Vertragsstaaten vorzunehmen sind, um Rechte in diesen Staaten zu erlangen. Da diese Handlungen einem ständigen Wandel unterworfen sind, sollte immer nur die neueste Ausgabe der Broschüre benutzt werden. Nachträgliche Informationen werden im Amtsblatt veröffentlicht.
2. **Übersetzung der europäischen Patentschrift nach Artikel 65 (1) des Europäischen Patentübereinkommens**
Sie werden erneut darauf hingewiesen, dass bestimmte Vertragsstaaten nach Artikel 65 (1) EPÜ eine Übersetzung der europäischen Patentschrift verlangen; hierauf wird in der Mitteilung gemäß Regel 71 (5) EPÜ verwiesen. Die Nichteinreichung dieser Übersetzung kann zur Folge haben, dass das Patent in dem betreffenden Staat/in den betreffenden Staaten als von Anfang an nicht eingetreten gilt. Weitere Einzelheiten entnehmen Sie bitte der oben genannten Broschüre.
3. **Zahlung von Jahresgebühren für europäische Patente**
Nach Artikel 141 EPU können "nationale" Jahresgebühren für das europäische Patent für die Jahre erhoben werden, die an das Jahr anschließen, in dem der Hinweis auf die Erteilung des europäischen Patents im "Europäischen Patentblatt" bekanntgemacht wird. Weitere Einzelheiten entnehmen Sie bitte der oben genannten Broschüre.

NOTE RELATING TO THE DECISION TO GRANT A
EUROPEAN PATENT (EPO Form 2006)

1. **EPO Information Brochure "National law relating to the EPC"**
This brochure provides useful information regarding formal requirements and the steps to be taken before the patent authorities of the Contracting States in order to acquire rights in those states. Since the necessary steps are subject to change the latest edition of the brochure should always be used. Subsequent information is published in the Official Journal.
2. **Translation of the European patent application under Article 65(1) of the European Patent Convention**
Your attention is again drawn to the requirements regarding translation of the European patent specification laid down by a number of Contracting States under Article 65(1) EPC, to which reference is made in the communication under Rule 71(5) EPC. Failure to supply such translation(s) may result in the patent being deemed to be void "ab initio" in the State(s) in question. For further details you are recommended to consult the above-mentioned brochure.
3. **Payment of renewal fees for European patents**
Under Article 141 EPC "national" renewal fees in respect of a European patent may be imposed for the years which follow that in which the mention of the grant of the European patent is published in the "European Patent Bulletin". For further details you are recommended to consult the above-mentioned brochure.

REMARQUE RELATIVE A LA DECISION DE DELIVRANCE
D'UN BREVET EUROPEEN (OEB Form 2006)

1. **Brochure d'information de l'OEB "Droit national relatif à la CBE"**
Cette brochure fournit d'utiles renseignements sur les conditions de forme requises et sur les actes à accomplir auprès des offices de brevet des Etats contractants aux fins d'obtenir des droits dans les Etats contractants. Etant donné que les actes indispensables sont susceptibles de modifications, il serait bon de toujours consulter la dernière édition de la brochure. Toute information ultérieure est publiée au Journal Officiel.
2. **Traduction du fascicule du brevet européen en vertu de l'article 65(1) de la Convention sur le brevet européen**
Votre attention est de nouveau attirée sur l'obligation faite par certains Etats contractants, en vertu de l'article 65(1) CBE, de fournir une traduction du fascicule du brevet européen, à laquelle il est fait référence dans la notification établie conformément à la règle 71(5) CBE. Si la(les) traduction(s) n'est(ne sont) pas fournie(s), le brevet européen peut, dès l'origine, être réputé sans effet dans cet(ces) Etat(s). Pour plus de détails, nous vous renvoyons à la brochure susmentionnée.
3. **Paiement des taxes annuelles pour le brevet européen**
Conformément à l'article 141 CBE des taxes annuelles "nationales" dues au titre du brevet européen peuvent être perçues pour les années suivant celle au cours de laquelle la mention de la délivrance du brevet européen est publiée au "Bulletin européen des brevets". Pour plus de détails, nous vous renvoyons à la brochure susmentionnée.

Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	4526528	
Application number	EP11862189.5	
Date of receipt	27 July 2016	
Receiving Office	European Patent Office, The Hague	
Your reference	JL69579P.EPA	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (2 p.) CLMSTRAN-DE-1.pdfJL69579P.EPA German claims.pdf (9 p.)	ep-sfd-request.xml CLMSTRAN-FR-1.pdfJL69579P.EPA French claims.pdf (8 p.) IGRA-1.pdfLTR_EPO_ONLINE_G&P _270716.pdf (1 p.)
Submitted by	CN=Mark Thurston 27885	
Method of submission	Online	
Date and time receipt generated	27 July 2016, 16:44 (CEST)	
Message Digest	B2:87:3E:2B:1C:8F:9D:A9:85:4E:23:D1:27:9A:06:B5:6A:D6:35:55	

Correction by the EPO of errors in debit instructions filed by eOLF

Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

European Patent Office
D-80298 Munchen
Germany

27 July 2016

Dear Sirs

European Patent Application No: 11862189.5
Applicant: Bell Helicopter Textron Inc.
Our ref: JL69579P.EPA

Following receipt of the Communication under Rule 71(3) EPC dated 5th July 2016 we hereby formally approve the text and attach translations of the claims of this application into French and German. The authorization to take the amount required to cover the grant and printing fees (namely €1865) from our Deposit Account No. 2805.0004 is indicated on the electronic EP Form 1038.

We look forward to being advised of the date of mention of grant in due course.

Yours faithfully

(signed electronically)

Mark R Thurston – Professional Representative

Barker Brettell LLP

Email: mark.thurston@barkerbrettell.co.uk

Revendications

1. Aéronef (201), comportant :
- un capteur (603) porté par l'aéronef (201), le capteur
5 (603) étant prévu pour détecter un mouvement directionnel (R1) de l'aéronef (201) ;
- un actionneur (615) porté par l'aéronef (201), l'actionneur (615) étant employé pour commander le mouvement directionnel (R1) de l'aéronef (201) ; et
- 10 un système (601) de commandes en communication de données avec le capteur (603) de l'aéronef et associé fonctionnellement à l'actionneur (615), le système de commandes comprenant :
- un modèle prévu pour découpler le mouvement
15 directionnel (R1) de l'aéronef en une équation latérale de mouvement et une équation longitudinale de mouvement ;
- une architecture de commande latérale en communication de données avec le modèle, l'architecture de commande latérale étant prévue pour employer l'équation latérale
20 de mouvement afin de commander le mouvement latéral de l'aéronef (201), l'architecture de commande latérale comportant :
- une boucle de commande latérale de vitesse sol sur le
25 côté (707) ;
- une boucle de commande latérale d'attitude en roulis (705) ; et
- une boucle de commande latérale de vitesse de roulis (703) ;

une architecture de commande longitudinale en communication de données avec le modèle, l'architecture de commande longitudinale étant prévue pour employer l'équation longitudinale de mouvement afin de commander
5 le mouvement longitudinal de l'aéronef (201) ; et
une logique (611) de consigne d'initialisation en communication de données avec l'architecture de commande latérale et en communication de données avec l'architecture de commande longitudinale ;
10 la logique (611) de consigne d'initialisation activant sélectivement l'architecture de commande latérale pour commander le mouvement latéral de l'aéronef (201) et activant sélectivement l'architecture de commande longitudinale pour commander le mouvement longitudinal
15 de l'aéronef (201) ; et
le système (601) de commandes employant l'architecture de commande latérale et l'architecture de commande longitudinale pour maintenir un cap à vecteur constant en parcourant une surface au sol tandis que l'aéronef
20 (201) vole avec un angle de crabe supérieur à zéro.

2. Aéronef selon la revendication 1, l'aéronef (201) comportant en outre :
une commande directionnelle, la commande directionnelle
25 étant manipulée par un pilote qui commande l'aéronef (201), la commande directionnelle étant en communication de données avec le système (601) de commandes.

30 3. Aéronef selon la revendication 2, l'architecture de commande directionnelle comportant :
une boucle de commande directionnelle de cap (805) ;
une boucle de commande directionnelle de coordination de virage (807) ; et
35 une boucle de commande directionnelle de vitesse de lacet (803).

4. Aéronef selon la revendication 2, comportant en outre :

un verrou de commande directionnelle (903) en communication de données avec l'architecture de commande directionnelle ;

le verrou de commande directionnelle (903) activant, à
5 mesure que la commande directionnelle est écartée d'une position de cran, un mouvement de virage à plat à vecteur constant.

5. Aéronef selon la revendication 1, comportant en
10 outre :

une commande latérale portée par l'aéronef (201), la commande latérale étant manipulée par un pilote qui commande l'aéronef (201), la commande latérale créant
15 une consigne latérale (702) en communication de données avec la boucle de commande latérale de vitesse sol sur le côté (707), la boucle de commande latérale d'attitude en roulis (705), et la boucle de commande latérale de vitesse de roulis (703).

20 6. Aéronef selon la revendication 5, comportant en outre :

un verrou de commande latérale (907) en communication de données avec le système (601) de commandes ;
le verrou de commande latérale (907) réinitialisant, à
25 mesure que la commande latérale est écartée d'une position de cran, un maintien (909) de vitesse latérale.

7. Aéronef selon la revendication 1, l'architecture
30 de commande longitudinale comportant :

une boucle de commande longitudinale de vitesse vers l'avant (605) ;
une boucle de commande longitudinale d'angle de tangage (607) ; et
35 une boucle de commande longitudinale de vitesse de tangage (609).

8. Aéronef selon la revendication 7, l'architecture de commande longitudinale comportant en outre :

une commande longitudinale portée par l'aéronef (201), la commande longitudinale étant manipulée par un pilote qui commande l'aéronef (201), la commande longitudinale créant une consigne longitudinale (613) en communication de données avec la boucle de commande longitudinale de vitesse vers l'avant (605), la boucle de commande longitudinale d'angle de tangage (607), et la boucle de commande longitudinale de vitesse de tangage (609).

10

9. Aéronef selon la revendication 8, comportant en outre :

un verrou de commande longitudinale (905) en communication de données avec le système (601) de commandes ;

le verrou de commande longitudinale (905) réinitialisant, à mesure que la commande longitudinale est écartée d'une position de cran, un maintien (911) de vitesse longitudinale.

20

10. Procédé de commande de virages en lacet à plat d'un aéronef (201) tout en maintenant un cap à vecteur constant en parcourant une surface au sol, le procédé comportant les étapes consistant à :

détecter un mouvement directionnel de l'aéronef (201) à l'aide d'un capteur (603) porté par l'aéronef (201), le mouvement directionnel présentant :

une direction longitudinale de mouvement ; et

une direction latérale de mouvement ;

commander le mouvement directionnel de l'aéronef (201) à l'aide d'un actionneur (615) associé fonctionnellement à l'aéronef (201) ;

mettre en place un système (601) de commandes en communication de données avec le capteur (603) de

l'aéronef et associé fonctionnellement à l'actionneur (615), le système (601) de commandes possédant :

un modèle ;

une architecture de commande latérale en communication de données avec le modèle, l'architecture de commande latérale comportant :

une boucle de commande latérale de vitesse sol sur le côté (707) ;

une boucle de commande latérale d'attitude en roulis (705) ; et

une boucle de commande latérale de vitesse de roulis ;

une architecture de commande longitudinale en communication de données avec le modèle ; et

une logique (611) de consigne d'initialisation en communication de données avec l'architecture de commande latérale et en communication de données avec l'architecture de commande longitudinale ;

découpler le mouvement directionnel de l'aéronef (201) en l'équation latérale de mouvement et l'équation longitudinale de mouvement à l'aide du modèle ;

commander la direction latérale de mouvement à l'aide d'une architecture de commande latérale, l'architecture de commande latérale employant l'équation latérale de mouvement ;

commander la direction longitudinale de mouvement à l'aide d'une architecture de commande longitudinale, l'architecture de commande longitudinale employant l'équation longitudinale de mouvement ; et

activer sélectivement l'architecture de commande latérale et l'architecture de commande longitudinale à l'aide de la logique (611) de consigne d'initialisation ;

le système (601) de commandes recevant des données de mouvement directionnel détecté en provenance du capteur (603) et commandant fonctionnellement les actionneurs (615), maintenant ainsi un vecteur constant en parcourant une surface au sol tandis que l'aéronef (201) vole avec un angle de crabe supérieur à zéro.

11. Procédé selon la revendication 10, le procédé comportant en outre l'étape consistant à :

fournir des consignes pour les virages en lacet à plat à l'aide d'une commande directionnelle manipulée par un pilote qui commande l'aéronef (201), la commande directionnelle étant associée fonctionnellement à une architecture de commande directionnelle, l'architecture de commande directionnelle étant en communication de données avec le système (601) de commandes.

12. Procédé selon la revendication 11, la fourniture des consignes pour les virages en lacet à plat à l'aide de l'architecture de commande directionnelle comportant les étapes consistant à :
communiquer des données via une boucle de commande directionnelle de cap (805) ;
communiquer des données via une boucle de commande directionnelle de coordination de virage (807) ; et
communiquer des données via une boucle de commande directionnelle de vitesse de lacet (803).

13. Procédé selon la revendication 11, comportant en outre l'étape consistant à :
activer le virage à plat à vecteur constant à l'aide d'un verrou de commande directionnelle (903) à mesure que la commande directionnelle est écartée d'une position de cran, le verrou de commande directionnelle (903) étant associé fonctionnellement à l'architecture de commande directionnelle.

14. Procédé selon la revendication 10, la commande de la direction latérale de mouvement à l'aide de l'architecture de commande latérale comportant les étapes consistant à :
communiquer des données de mouvement latéral via une boucle de commande latérale de vitesse sol sur le côté (707) ;
communiquer des données de mouvement latéral via une boucle de commande latérale d'attitude en roulis (705) ; et

communiquer des données de mouvement latéral via une boucle de commande latérale de vitesse de roulis (703).

15. Procédé selon la revendication 10, comportant en
5 outre l'étape consistant à :
commander la direction latérale de mouvement à l'aide
d'une commande latérale manipulée par un pilote qui
commande l'aéronef (201), la commande latérale étant
associée fonctionnellement à l'architecture de commande
10 latérale.

16. Procédé selon la revendication 15, comportant en
outre l'étape consistant à :
réinitialiser un maintien (909) de vitesse latérale à
15 l'aide d'un verrou de commande latérale (907) à mesure
que la commande latérale est écartée d'une position de
cran, le verrou de commande latérale (907) étant en
communication de données avec l'architecture de
commande latérale.

20
17. Procédé selon la revendication 16, la commande de
la direction longitudinale de mouvement à l'aide de
l'architecture de commande longitudinale comportant les
étapes consistant à :
25 communiquer des données de mouvement longitudinal via
une boucle de commande longitudinale de vitesse vers
l'avant (605) ;
communiquer des données de mouvement longitudinal via
une boucle de commande longitudinale d'angle de tangage
30 (607) ; et
communiquer des données de mouvement longitudinal via
une boucle de commande longitudinale de vitesse de
tangage (609).

35 18. Procédé selon la revendication 10, l'architecture
de commande longitudinale comportant en outre :
la commande de la direction longitudinale de mouvement
à l'aide d'une commande longitudinale manipulée par un
pilote qui commande l'aéronef (201), la commande

longitudinale étant associée fonctionnellement à l'architecture de commande longitudinale.

19. Procédé selon la revendication 18, comportant en
5 outre l'étape consistant à :
réinitialiser un maintien (911) de vitesse
longitudinale à l'aide d'un verrou de commande
longitudinale (905) à mesure que la commande
longitudinale est écartée d'une position de cran, le
10 verrou de commande longitudinale (905) étant en
communication de données avec l'architecture de
commande longitudinale.

Ansprüche

1. Flugzeug (201), umfassend:
 - 5 einen Sensor (603), der durch das Flugzeug (201) getragen wird, wobei der Sensor (603) dazu ausgelegt ist, eine direktionale Bewegung (R1) des Flugzeugs (201) zu erfassen;
 - 10 einen Aktuator (615), der durch das Flugzeug (201) getragen wird, wobei der Aktuator (615) benutzt wird, um die direktionale Bewegung (R1) des Flugzeugs (201) zu steuern; und
 - 15 ein Steuersystem (601) in einer Datenverbindung mit dem Flugzeugsensor (603), das mit dem Aktuator (615) betrieblich verbunden ist, wobei das Steuersystem Folgendes aufweist:
 - 20 ein Modell, das dazu ausgelegt ist, die direktionale Bewegung (R1) des Flugzeugs in eine Querbewegungsgleichung und eine Längsbewegungsgleichung zu entkoppeln;
 - 25 eine Quersteuerarchitektur in einer Datenverbindung mit dem Modell, wobei die Quersteuerarchitektur dazu ausgelegt ist, die Querbewegungsgleichung zu benutzen, um die Querbewegung des Flugzeugs (201) zu steuern,
 - 30 wobei die Querbewegungsarchitektur

eine Quer-Steuerschleife für die
seitliche Geschwindigkeit über Grund
(707);

5 eine Quer-Rolllagen-Steuerschleife
(705); und

eine Quer-Rollraten-Steuerschleife (703)

10 umfasst;

eine Längssteuerarchitektur in einer
Datenverbindung mit dem Modell, wobei die
Längssteuerarchitektur dazu ausgelegt ist,
15 die Längsbewegungsgleichung zu benutzen, um
die Längsbewegung des Flugzeugs (201) zu
steuern; und

eine Initialisierungsbefehlslogik (611) in
20 einer Datenverbindung mit der
Quersteuerarchitektur und in einer
Datenverbindung mit der
Längssteuerarchitektur;

25 wobei die Initialisierungsbefehlslogik (611)
die Quersteuerarchitektur selektiv aktiviert,
um die Querbewegung des Flugzeugs (201) zu
steuern, und die Längssteuerarchitektur
selektiv aktiviert, um die Längsbewegung des
30 Flugzeugs (201) zu steuern; und

wobei das Steuersystem (601) die
Quersteuerarchitektur und die
Längssteuerarchitektur benutzt, um einen Kurs
35 mit konstantem Vektor über eine Bodenfläche
beizubehalten, während das Flugzeug (201) mit
einem Schiebewinkel von mehr als null fliegt.

2. Flugzeug nach Anspruch 1, wobei das Flugzeug (201) ferner Folgendes umfasst:
- 5 eine direktionale Steuerung, wobei die direktionale Steuerung durch einen Piloten, der das Flugzeug (201) steuert, manipuliert wird, wobei die direktionale Steuerung in einer Datenverbindung mit dem Steuersystem (601) steht.
- 10 3. Flugzeug nach Anspruch 2, wobei die direktionale Steuerarchitektur Folgendes umfasst:
- eine direktionale Kurs-Steuerschleife (805);
- 15 eine direktionale Drehkoordinations-Steuerschleife (807); und
- eine direktionale Gierraten-Steuerschleife (803).
- 20 4. Flugzeug nach Anspruch 2, ferner umfassend:
- eine direktionale-Steuerverriegelung (903) in einer Datenverbindung mit der direktionalen Steuerarchitektur;
- 25 wobei die direktionale Steuerverriegelung (903) eine Gierbewegung mit konstantem Vektor aktiviert, wenn die direktionale Steuerung aus einer Rastposition bewegt wird.
- 30 5. Flugzeug nach Anspruch 1, ferner umfassend:
- eine Quersteuerung, die durch das Flugzeug (201) ausgeführt wird, wobei die Quersteuerung durch
- 35 einen Piloten, der das Flugzeug (201) steuert, manipuliert wird, wobei die Quersteuerung einen Querbefehl (702) in einer Datenverbindung mit der Quer-Steuerschleife für die seitliche Geschwindigkeit über Grund (707); der Quer-

Rolllagen-Steuerschleife (705); und der Quer-Rollraten-Steuerschleife (703) steht.

6. Flugzeug nach Anspruch 5, ferner umfassend:

5

eine Quersteuerverriegelung (907) in einer Datenverbindung mit dem Steuersystem (601);

10 wobei die Quersteuerverriegelung (907) eine beibehaltene Quergeschwindigkeit (909) zurücksetzt, wenn die Quersteuerung aus einer Rastposition bewegt wird.

- 15 7. Flugzeug nach Anspruch 1, wobei die Längssteuerarchitektur Folgendes umfasst:

eine Längs-Vorwärtsgeschwindigkeits-Steuerschleife (605);

20 eine Längs-Nickwinkel-Steuerschleife (607); und

eine Längs-Nickraten-Steuerschleife (609).

- 25 8. Flugzeug nach Anspruch 7, wobei die Längssteuerarchitektur ferner Folgendes umfasst:

30 eine Längssteuerung, die durch das Flugzeug (201) getragen wird, wobei die Längssteuerung durch einen Piloten, der das Flugzeug (201) steuert, manipuliert wird, wobei die Längssteuerung einen Längsbefehl (613) in einer Datenverbindung mit der Längs-Vorwärtsgeschwindigkeits-Steuerschleife (605), der Längs-Nickwinkel-Steuerschleife (607) und der Längs-Nickraten-Steuerschleife (609) erzeugt.

35

9. Flugzeug nach Anspruch 8, ferner umfassend:

eine Längssteuerverriegelung (905) in einer Datenverbindung mit dem Steuersystem (601);

5 wobei die Längssteuerverriegelung (905) eine beibehaltene Längsgeschwindigkeit (911) zurücksetzt, wenn die Längssteuerung aus einer Rastposition bewegt wird.

10 10. Verfahren zur Steuerung des Gierens eines Flugzeugs (201), während ein Kurs mit einem konstanten Vektor über eine Bodenfläche beibehalten wird, wobei das Verfahren Folgendes umfasst:

15 Erfassen einer direktionalen Bewegung des Flugzeugs (201) mit einem Sensor (603), der durch das Flugzeug (201) getragen wird, wobei die direktionale Bewegung

20 eine Längsbewegungsrichtung; und

eine Querbewegungsrichtung

aufweist;

25 Steuern der direktionalen Bewegung des Flugzeugs (201) mit einem Aktuator (615), der betrieblich mit dem Flugzeug (201) verbunden ist;

30 Bereitstellen eines Steuersystems (601) in einer Datenverbindung mit dem Flugzeugsensor (603), das betrieblich mit dem Aktuator (615) verbunden ist, wobei das Steuersystem (601)

35 ein Modell;

eine Quersteuerarchitektur in einer Datenverbindung mit dem Modell, wobei die Quersteuerarchitektur

eine Quer-Steuerschleife für die
seitliche Geschwindigkeit über Grund
(707);

5 eine Quer-Rolllagen-Steuerschleife
(705); und

eine Quer-Rollraten-Steuerschleife

10 umfasst;

eine Längssteuerarchitektur in einer
Datenverbindung mit dem Modell; und

15 eine Initialisierungsbefehlslogik (611) in
einer Datenverbindung mit der
Quersteuerarchitektur und in einer
Datenverbindung mit der
Längssteuerarchitektur

20 umfasst;

Entkoppeln der direktionalen Bewegung des
Flugzeugs (201) durch das Modell in die
25 Querbewegungsgleichung und die
Längsbewegungsgleichung;

Steuern der Querbewegungsrichtung mit einer
Quersteuerarchitektur, wobei die
30 Quersteuerarchitektur die Querbewegungsgleichung
benutzt;

Steuern der Längsbewegungsrichtung mit einer
Längssteuerarchitektur, wobei die
35 Längssteuerarchitektur die Längsbewegungsgleichung
benutzt; und

selektives Aktivieren der Quersteuerarchitektur und der Längssteuerarchitektur mit der Initialisierungsbefehlslogik (611);

5 wobei das Steuersystem (601) erfasste direktionale Bewegungsdaten von dem Sensor (603) erhält und die Aktuatoren (615) betrieblich steuert, wodurch ein konstanter Vektor über eine Bodenfläche beibehalten wird, während das Flugzeug (201) mit
10 einem Schiebewinkel von mehr als null fliegt.

11. Verfahren nach Anspruch 10, wobei das Verfahren ferner Folgendes umfasst:

15 Befehlen des Gierens mit einer direktionalen Steuerung, die durch einen Piloten, der das Flugzeug (201) steuert, manipuliert wird, wobei die direktionale Steuerung betrieblich mit einer direktionalen Steuerarchitektur verbunden ist,
20 wobei die direktionale Steuerarchitektur in einer Datenverbindung mit dem Steuersystem (601) steht.

12. Verfahren nach Anspruch 11, wobei das Befehlen des Gierens mit der direktionalen Steuerarchitektur
25 Folgendes umfasst:

Kommunizieren von Daten durch eine direktionale Kurs-Steuerschleife (805);

30 Kommunizieren von Daten durch eine direktionale Drehkoordinations-Steuerschleife (807); und

Kommunizieren von Daten durch eine direktionale Gierraten-Steuerschleife (803).

35

13. Verfahren nach Anspruch 11, ferner umfassend:

Aktivieren des Gierens mit konstantem Vektor mit einer direktionalen Steuerverriegelung (903), wenn

die direktionale Steuerung aus einer Rastposition bewegt wird, wobei die direktionale Steuerverriegelung (903) betrieblich mit der direktionalen Steuerarchitektur verbunden ist.

5

14. Verfahren nach Anspruch 10, wobei das Steuern der Querbewegungsrichtung mit der Quersteuerarchitektur Folgendes umfasst:

10 Kommunizieren von Querbewegungsdaten durch eine Quer-Steuerschleife für die seitliche Geschwindigkeit über Grund (707);

15 Kommunizieren von Querbewegungsdaten durch eine Quer-Rolllagen-Steuerschleife (705); und

Kommunizieren von Querbewegungsdaten durch eine Quer-Rollraten-Steuerschleife (703).

20 15. Verfahren nach Anspruch 10, ferner umfassend:

25 Steuern der Querbewegungsrichtung mit einer Quersteuerung, die durch einen Piloten, der das Flugzeug (201) steuert, manipuliert wird, wobei die Quersteuerung betrieblich mit der Quersteuerarchitektur verbunden ist.

16. Verfahren nach Anspruch 15, ferner umfassend:

30 Zurücksetzen einer beibehaltenen Quergeschwindigkeit (909) mit einer Querstauverriegelung (907), wenn die Quersteuerung aus einer Rastposition bewegt wird, wobei die Querstauverriegelung (907) in einer
35 Datenverbindung mit der Quersteuerarchitektur steht.

17. Verfahren nach Anspruch 16, wobei das Steuern der
Längsbewegungsrichtung mit der
Längssteuerverriegelung Folgendes umfasst:
Kommunizieren von Längsbewegungsdaten durch eine
5 Längs-Vorwärtsgeschwindigkeits-Steuerschleife
(605);
- Kommunizieren von Längsbewegungsdaten durch eine
Längs-Nickwinkel-Steuerschleife (607); und
10 Kommunizieren von Längsbewegungsdaten durch eine
Längs-Nickraten-Steuerschleife (609).
18. Verfahren nach Anspruch 10, wobei die
15 Längssteuerverriegelung ferner Folgendes umfasst:
- Steuern der Längsbewegungsrichtung mit einer
Längssteuerung, die durch einen Piloten, der das
Flugzeug (201) steuert, manipuliert wird, wobei
20 die Längssteuerung betrieblich mit der
Längssteuerverriegelung verbunden ist.
19. Verfahren nach Anspruch 18, ferner umfassend:
- 25 Zurücksetzen einer beibehaltenen
Längsgeschwindigkeit (911) mit einer
Längssteuerverriegelung (905), wenn die
Längssteuerung aus einer Rastposition bewegt wird,
wobei die Längssteuerverriegelung (905) in einer
30 Datenverbindung mit der Längssteuerverriegelung
steht.



Letter accompanying subsequently filed items

Representative:

Dr Mark Thurston
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham West Midlands B16 8QQ
United Kingdom

Phone: +44(0) 121 456 0000

Fax: +44(0) 121 456 1368

E-mail: mark.thurston@barkerbrettell.co.uk

80298 Munich

Germany

Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818

NL-2280 HV Rijswijk

Netherlands

Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin

Germany

Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number

11862189.5

Applicant's or representative's reference

JL69579P.EPA

	Description of document	Original file name	Assigned file name
1	French translations of the claims	JL69579P.EPA French claims.pdf	CLMSTRAN-FR-1.pdf
2	German translations of the claims	JL69579P.EPA German claims.pdf	CLMSTRAN-DE-1.pdf
3	Reply to the communication under rule 71(3) EPC	LTR_EPO_ONLINE_G&P_270716.pdf	IGRA-1.pdf

	Fees	Factor applied	Fee schedule	Amount to be paid
15-1	007 Fee for grant, including fee for publication of the European patent specification (R71(3))	1	925.00	925.00
15-2	016 Claims fee in accordance with R. 71(4) - For the 16th to the 50th claim (after 01.04.2009) / Claims fee in accordance with R. 71(4) (before 01.04.2009)	4	235.00	940.00
	Total:		EUR	1 865.00

	Payment	
1	Mode of payment	Debit from deposit account
	Currency:	EUR
	The European Patent Office is hereby authorised, to debit from the deposit account with the EPO any fees and costs indicated on the fees page.	
	Deposit account number:	28050004
	Account holder:	Barker Brettell LLP
2	Refund/Reimbursement	
	Reimbursement (if any) to be made to EPO deposit account:	28050004
	Account holder:	Barker Brettell LLP

Signatures

Place:

Derbyshire, UK

JL69579P.EPA

Date:	27 July 2016
Signed by:	Mark Thurston 27885
Representative name:	Mark Thurston
Capacity:	(Representative)

Annex to EPO Form 2004, Communication pursuant to Rule 71(3) EPC

Bibliographical data of European patent application No. 11 862 189.5

For the intended grant of the European patent, the bibliographical data are set out below, for information:

Title of invention:

- FLUGSTEUERUNGSFORMELN FÜR GIEREN BEI KONSTANTEM FLUGVEKTOR
- FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS
- LOIS DE COMMANDE DE VOL POUR VIRAGES À PLAT À VECTEUR CONSTANT

Classification: INV. G05D1/08 B64C19/00

Date of filing: 30.03.2011

Priority claimed:

Contracting States*
for which fees have
been paid:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU
LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

Extension States*
for which fees have
been paid:

Validation States*
for which fees have
been paid:

Applicant(s):** Bell Helicopter Textron Inc.
P.O. Box 482
Fort Worth, TX 76101
US

Inventor(s): CHRISTENSEN, Kevin, Thomas
3905 Branchwood Drive
Plano
TX 75093
US

SHUE, Shyhpyng, Jack
2809 Woodland Hills Drive
Grapevine
TX 76051
US

CAUDILL, Troy, Sheldon
6195 Oak Hollow Drive
Burleson
TX 76028
US

- *) If the time limit for the payment of designation fees according to Rule 39(1) EPC has not yet expired and the applicant has not withdrawn any designation, **all Contracting States/Extension States/Validation States** are currently still deemed to be designated. See also Rule 71a(3) EPC and, if applicable, the above Note to users of the automatic debiting procedure.
- **) If two or more applicants have designated different Contracting States, this is indicated here.



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME-UNI

Formalities Officer
Name: Novoa, Carlos
Tel: +49 89 2399 - 2718
or call
+31 (0)70 340 45 00

Application No. 11 862 189.5 - 1802	Ref. JL69579P.EPP	Date 05.07.2016
Applicant Bell Helicopter Textron Inc.		

Communication under Rule 71(3) EPC

1. Intention to grant

You are informed that the examining division intends to grant a European patent on the basis of the above application, with the text and drawings and the related bibliographic data as indicated below.

A copy of the relevant documents is enclosed.

1.1 In the text for the Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT
RO RS SE SI SK SM TR

Description, Pages

2, 5-12	as published	
1, 1a, 3, 4, 13	filed in electronic form on	26-06-2015

Claims, Numbers

1-19	filed in electronic form on	24-02-2016
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Drawings, Sheets

1/9-9/9	as published
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1.2 Bibliographic data

The title of the invention in the three official languages of the European Patent Office, the international patent classification, the designated contracting states, the registered name(s) of the applicant(s) and the other bibliographic data are shown on **EPO Form 2056** (enclosed).

2. Invitation

You are invited, **within a non-extendable period of four months** of notification of this communication,

2.1 to EITHER approve the text communicated above and verify the bibliographic data (Rule 71(5) EPC)

(1) by filing a translation of the claim(s) in the other two official languages of the EPO

Fee code	EUR
----------	-----

(2a) by paying the fee for grant including the fee for publication:
minus any amount already paid (Rule 71a(5) EPC):

007	925.00
	0.00

Total amount:	925.00
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(3) by paying additional claims fees under Rule 71(4) EPC;
number of claims fees payable: 4
minus any amount already paid (Rule 71a(5) EPC):

016	940.00
	0.00

Total amount:	940.00
---------------	--------

Important: If the translations of the claims and fees have already been filed and paid respectively in reply to a previous communication under Rule 71(3) EPC, e.g. in the case of resumption of examination after approval (see Guidelines C-V, 6), **agreement as to the text to be granted** (Rule 71a(1) EPC) must be expressed within the same time limit (e.g. by approving the text and verifying the bibliographic data, by confirming that grant proceedings can go ahead with the documents on file and/or by stating which translations of the claims already on file are to be used).

Note 1: See "Important notes concerning fee payments" below.

Note 2: Any overpaid "minus" amounts will be refunded when the decision to grant (EPO Form 2006A) has been issued.

Note 3: For the calculation of the grant fee under Article 2(2), No. 7, RFees (old fee structure), the number of pages is determined on the basis of a clean copy of the application documents, in which text deleted as a result of any amendments by the examining division is not shown. Such clean copy is made available via on-line file inspection only.

2.2 OR, in the case of disapproval, to request reasoned amendments or corrections to the text communicated above or keep to the latest text submitted by you (Rule 71(6) EPC).

In this case the translations of the claims and fee payments mentioned under point 2.1 above are NOT due.

The terms "amendment(s)" and "correction(s)" refer only to amendments or corrections of the application documents and not of other documents (e.g. bibliographic data, the designation of the inventor, etc.).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the examining division requesting that you correct this deficiency (Rule 137(4) EPC).

2.3 Bibliographic data

Where you request a change or correction of bibliographic data in response to the Rule 71(3) communication, this will **not** cause the sending of a further communication under Rule 71(3) EPC. You will still have to pay the fees and file translations in reply to the Rule 71(3) communication in the case of 2.1 above, unless you also file a reasoned request for amendments or corrections in response to the Rule 71(3) communication (see case 2.2 above).

3. Loss of rights

If neither of the two possible actions above (see points 2.1 or 2.2) is performed in due time, the European patent application will be deemed to be withdrawn (Rule 71(7) EPC).

4. Further procedure

4.1 In the case of point 2.1 above

- 4.1.1** The decision to grant the European patent will be issued, and the **mention of the grant** of the patent will be published in the European Patent Bulletin, if the requirements concerning the translation of the claims and the payment of all fees are fulfilled and there is agreement as to the text to be granted (Rule 71a(1) EPC).

Note on payment of the renewal fee:

If a renewal fee becomes due before the next possible date for publication of the mention of the grant of the European patent, publication will be effected only after the renewal fee and any additional fee have been paid (Rule 71a(4) EPC).

Under Article 86(2) EPC, the obligation to pay renewal fees to the European Patent Office terminates with the payment of the renewal fee due in respect of the year in which the mention of the grant of the European patent is published.

Note on payment of the designation fee(s):

If the designation fee(s) become(s) due after the communication under Rule 71(3) EPC, the mention of the grant of the European patent will not be published until these fees have been paid (Rule 71a(3) EPC).

- 4.1.2** After publication, the **European patent specification** can be downloaded free of charge from the EPO publication server <https://data.epo.org/publication-server> or ordered from the Vienna sub-office upon payment of a fee (OJ EPO 2005, 126).

4.1.3 Filing of translations in the contracting states

As regards translation requirements prescribed by the contracting states under Article 65(1) EPC, please consult the website of the European Patent Office

www.epo.org → Law & practice → Legal texts, National law relating to the EPC

www.epo.org → Law & practice → All Legal texts → London Agreement

In the case of a valid extension or validation

As regards translation requirements prescribed by the extension or validation states, please consult the website of the European Patent Office

www.epo.org → Law & practice → Legal texts, National law relating to the EPC

Failure to supply a prescribed translation in a contracting state, or in an extension or validation state may result in the patent being deemed to be void *ab initio* in the state concerned (Art. 65(3) EPC).

4.2 In the case of 2.2 above

If the present communication under Rule 71(3) EPC is based on an auxiliary request and, within the time limit, you maintain the main request or a higher ranking request which is not allowable, the application will be refused (Art. 97(2) EPC).

If the examining division gives its consent to the requested amendments or corrections, it will issue a new communication under Rule 71(3) EPC; otherwise, it shall resume the examination proceedings (Rule 71(6) EPC).

5. Filing of a divisional application

Any divisional application relating to this European patent application must be filed directly with the European Patent Office in Munich, The Hague or Berlin and will be in the language of the proceedings for the present application, or if the latter was not in an official language of the EPO, the divisional application may be filed in the language of the present application as filed (see Article 76(1) and Rule 36(2) EPC). Any such divisional application must be filed while the present application is still pending (Rule 36(1) EPC; Guidelines A-IV, 1.1.1).

6. Important notes concerning fee payments

6.1 For all payments, please refer to the relevant **fee code(s)**.

6.2 Automatic debiting procedure

The fee for grant, including the fee for publication, and any additional claims fees due under Rule 71(4) EPC will be debited automatically on the date of filing of the translations of the claims, or on the last day of the period of this communication. However, if the designation fee(s) become(s) due as set out in Rule 71a(3) EPC and/or a renewal fee becomes due as set out in Rule 71a(4) EPC, these should be paid separately by another permitted way of payment in order not to delay the publication of the mention of the grant. The same applies in these circumstances to the payment of extension and validation fees. For further details see the Arrangements for the automatic debiting procedure (AAD) and accompanying information from the EPO concerning the automatic debiting procedure (Annexes A.1 and A.2 to the Arrangements for deposit accounts (ADA) in Supplementary publication - OJ EPO 3/2015).

Note: If a waiver is expressed in response to a Rule 71(3) communication (see OJ EPO 2015, A52), the fee for grant, including the fee for publication/printing, and any additional claims fees will not be debited automatically. These fees must be paid separately by another means of payment allowed under the Rules relating to Fees.

6.3 Important information relating to fee amounts

Following any amendment to the Rules relating to Fees, the amount(s) mentioned in this communication may be different from the amount(s) **actually due on the date of payment**. The latest version of the Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, is also available on the EPO website (www.epo.org) and can be found under www.epo.org/schedule-of-fees, which allows the viewing, downloading and searching for individual fee amounts, both current and previous.

Please note that procedural fees are usually adjusted every two years, on even years, with effect from 1 April.

Examining Division:

Chairman:	Vañó Gea, Joaquín
2nd Examiner:	Lalinde, Rafael
1st Examiner:	Pöllmann, H



Novoa, Carlos
For the Examining Division
Tel. No.: +49 89 2399 - 2718

Enclosures: Text intended for grant
 EPO Form 2056

Application No.:

11 862 189.5

IV.2. Patent classification

The classification has been changed. It now is as follows:

INV. G05D1/08 B64C19/00

IV.3. Title of the invention

The title has been changed. It now is as follows:

FLUGSTEUERUNGSFORMELN FÜR GIEREN BEI KONSTANTEM FLUGVEKTOR

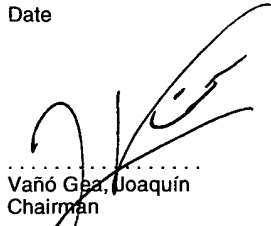
FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

LOIS DE COMMANDE DE VOL POUR VIRAGES À PLAT À VECTEUR CONSTANT

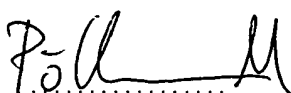
IV.4. Documentation

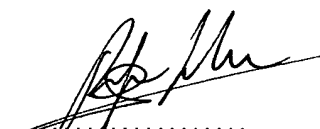
15.6.2016

Date


Vaño Giza, Joaquín
Chairman

Enclosure(s):


Pöllmann, H
1st examiner


Lalinde, Rafael
2nd examiner

- 1 -

FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Technical Field

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.

Description of the Prior Art

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.

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.

An example velocity command system is described in US 5553812, in which an aircraft flight path referenced velocities are determined with respect to an inertial frame of reference, the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that the aircraft maintains a fixed inertial referenced flight path regardless of the pointing direction of the aircraft. Velocity control with respect to an inertial frame of reference is accomplished by controlling the aircraft flight path

- 1a -

based on aircraft body referenced commanded lateral and longitudinal acceleration and based on aircraft body referenced lateral and longitudinal centrifugal acceleration. Operation in the velocity stabilization mode is provided in response to the manual activation of the velocity stabilization mode by the pilot, provided that the aircraft is already operating in the ground speed mode and the aircraft is not in a coordinated turn.

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.

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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.

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

Brief Description of the Drawings

The novel features believed characteristic of the application are set forth in the appended claims. However, the application itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood with 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;

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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;

5 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

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

Description of the Preferred Embodiment

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
15 Constant Vector Flat Turn (CVFT) mode. As a result of this auto-moding logic, the

- 4 -

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.

5 The auto-moding logic 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
10 having to use cockpit switches to change modes.

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
15 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.

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
20 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.

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

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- 5 -

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.

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.

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.

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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 pedal turn is applied to rotate aircraft 201 in a forward heading with a pedal 203. In the preferred embodiment, pedal 203 is a pedal 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 pedal 203. For purposes of this invention, a lateral controller, longitudinal controller, and directional controller are characterized as pedal 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.

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 pedal turn is applied to rotate aircraft 201 such that the forward flight of aircraft 201 changes to a sideward flight heading.

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

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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.

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.

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 a minimum, thus stabilizing the system.

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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-initialize inactive loops in order to eliminate control jumps when switching between the loops to provide seamless and transient free mode changes.

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.

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.

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,

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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).

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".

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.

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

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

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.

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

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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).

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"

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.

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.

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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.

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.

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:

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

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

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.

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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.

Both longitudinal speed hold 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).

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

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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.

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Claims

1. An aircraft (201), comprising:

a sensor (603) carried by the aircraft (201), the sensor (603) being adapted to sense a directional movement (R1) of the aircraft (201);

5 an actuator (615) carried by the aircraft (201), the actuator (615) being utilized to control the directional movement (R1) of the aircraft (201); and

a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system having:

10 a model adapted to decouple the directional movement (R1) 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 (201), the lateral control architecture comprising:

15 a lateral sideward groundspeed control loop (707);
a lateral roll attitude control loop (705); and
a lateral roll rate control loop (703);

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 (201); and

20 an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

25 wherein the initialization command logic (611) selectively activates the lateral control architecture for controlling the lateral motion of the aircraft (201) and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft (201); and

wherein the control system (601) utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading

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across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

2. The aircraft of claim 1, the aircraft (201) further comprising:

5 a directional controller, the directional controller being manipulated by a pilot controlling the aircraft (201), the directional controller being in data communication with the control system (601).

3. The aircraft of claim 2, the directional control architecture comprising:

10 a directional heading control loop (805);
a directional turn coordination control loop (807); and
a directional yaw rate control loop (803).

4. The aircraft of claim 2, further comprising:

15 a directional control latch (903) in data communication with the directional control architecture;

wherein, as the directional controller is moved out of a detent position, the directional control latch (903) activates a constant vector flat turn motion.

5. The aircraft of claim 1, further comprising:

20 a lateral controller carried by the aircraft (201), the lateral controller being manipulated by a pilot controlling the aircraft (201), the lateral controller creating a lateral command (702) in data communication with the lateral sideward groundspeed control loop (707), the lateral roll attitude control loop (705), and the lateral roll rate
25 control loop (703).

6. The aircraft of claim 5, further comprising:

30 a lateral control latch (907) in data communication with the control system (601);
wherein, as the lateral controller is moved out of a detent position, the lateral control latch (907) resets a lateral speed hold (909).

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7. The aircraft of claim 1, the longitudinal control architecture comprising:
a longitudinal forward speed control loop (605);
a longitudinal pitch angle control loop (607); and
a longitudinal pitch rate control loop (609).

5

8. The aircraft of claim 7, the longitudinal control architecture further comprising:
a longitudinal controller carried by the aircraft (201), the longitudinal controller
being manipulated by a pilot controlling the aircraft (201), the longitudinal controller
creating a longitudinal command (613) in data communication with the longitudinal
forward speed control loop (605), the longitudinal pitch angle control loop (607), and the
longitudinal pitch rate control loop (609).

10

9. The aircraft of claim 8, further comprising:
a longitudinal control latch (905) in data communication with the control system
(601);
wherein, as the longitudinal controller is moved out of a detent position, the
longitudinal control latch (905) resets a longitudinal speed hold (911).

15

10. A method to control flat yawing turns of an aircraft (201) while maintaining a
constant vector heading across a ground surface, the method comprising:

20

sensing a directional movement of the aircraft (201) with a sensor (603) carried
by the aircraft (201), the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

controlling the directional movement of the aircraft (201) with an actuator (615)
operably associated with the aircraft (201);

25

providing a control system (601) in data communication with the aircraft sensor
(603) and operably associated with the actuator (615), the control system (601) having:

a model;

a lateral control architecture in data communication with the model, the
lateral control architecture comprising:

30

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a lateral sideward groundspeed control loop (707);

a lateral roll attitude control loop (705); and

a lateral roll rate control loop;

a longitudinal control architecture in data communication with the model;

5 and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

10 decoupling the directional movement of the aircraft (201) 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;

15 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 (611);

20 wherein the control system (601) receives sensed directional movement data from the sensor (603) and operably controls the actuators (615), thus maintaining a constant vector across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

11. The method of claim 10, the method further comprising:

25 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft (201), the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system (601).

30 12. The method of claim 11, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop (805);

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communicating data through a directional turn coordination control loop (807);

and

communicating data through a directional yaw rate control loop (803).

5 13. The method of claim 11, further comprising:
 activating the constant vector flat turn with a directional control latch (903) as the
 directional controller is moved out of a detent position, the directional control latch (903)
 being operably associated with the directional control architecture.

10 14. The method of claim 10 wherein controlling the lateral direction of motion with the
 lateral control architecture comprises:

 communicating lateral motion data through a lateral sideward groundspeed
 control loop (707);

 communicating lateral motion data through a lateral roll attitude control loop
15 (705); and

 communicating lateral motion data through a lateral roll rate control loop (703).

15. The method of claim 10, further comprising:

 controlling the lateral direction of motion with a lateral controller manipulated by a
20 pilot controlling the aircraft (201), the lateral controller being operably associated with
 the lateral control architecture.

16. The method of claim 15, further comprising:

 resetting a lateral speed hold (909) with a lateral control hatch (907) as the lateral
25 controller is moved out of a detent position, the lateral control hatch (907) being in data
 communication with the lateral control architecture.

17. The method of claim 16, wherein controlling the longitudinal direction of motion
 with the longitudinal control architecture comprises:

30 communicating longitudinal motion data through a longitudinal forward speed
 control loop (605);

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communicating longitudinal motion data through a longitudinal pitch angle control loop (607); and

communicating longitudinal motion data through a longitudinal pitch rate control loop (609).

5

18. The method of claim 10, the longitudinal control architecture further comprising:

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft (201), the longitudinal controller being operably associated with the longitudinal control architecture.

10

19. The method of claim 18, further comprising:

resetting a longitudinal speed hold (911) with a longitudinal control hatch (905) as the longitudinal controller is moved out of a detent position, the longitudinal control hatch (905) being in data communication with the longitudinal control architecture.

15

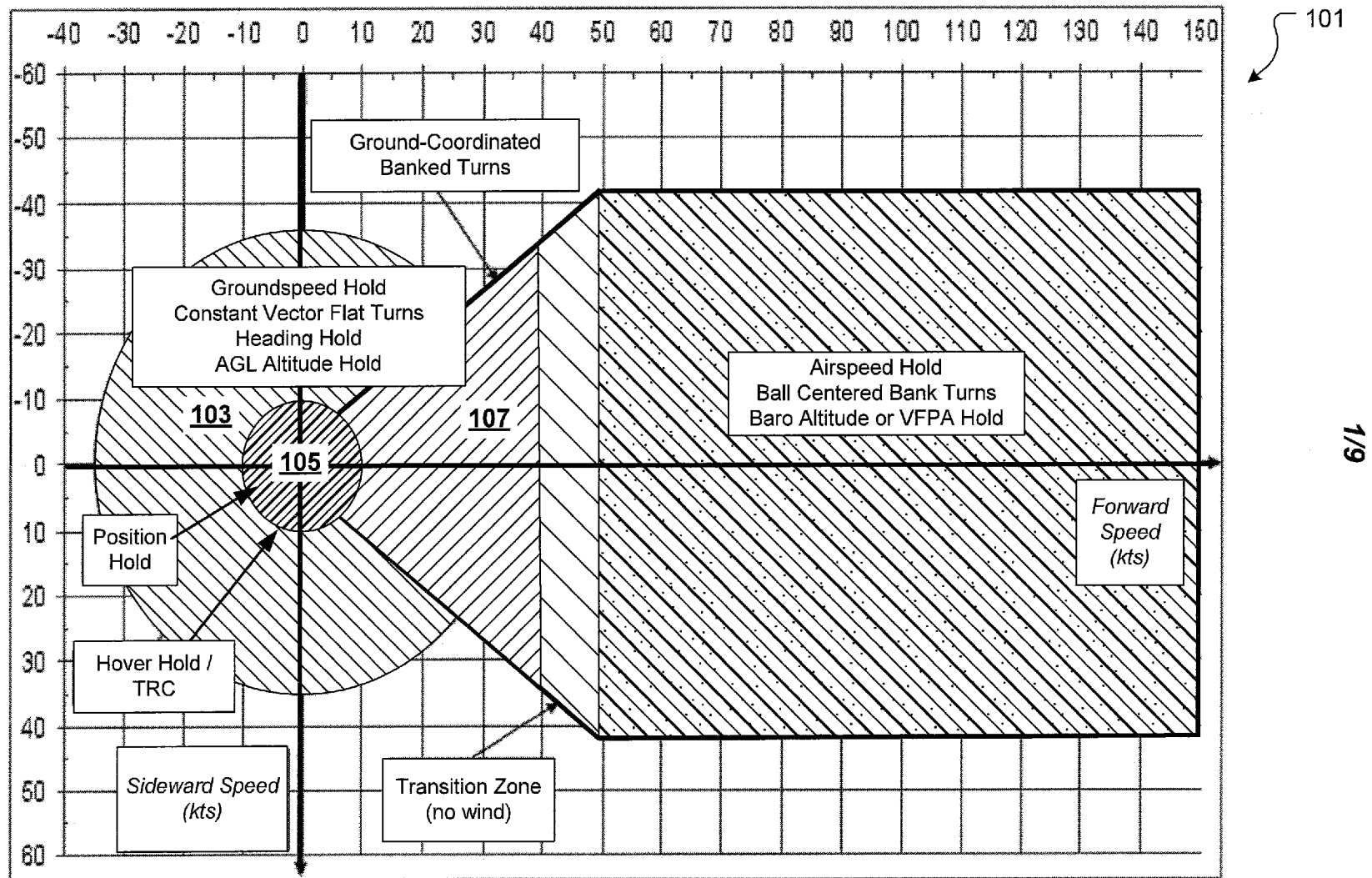


FIG. 1

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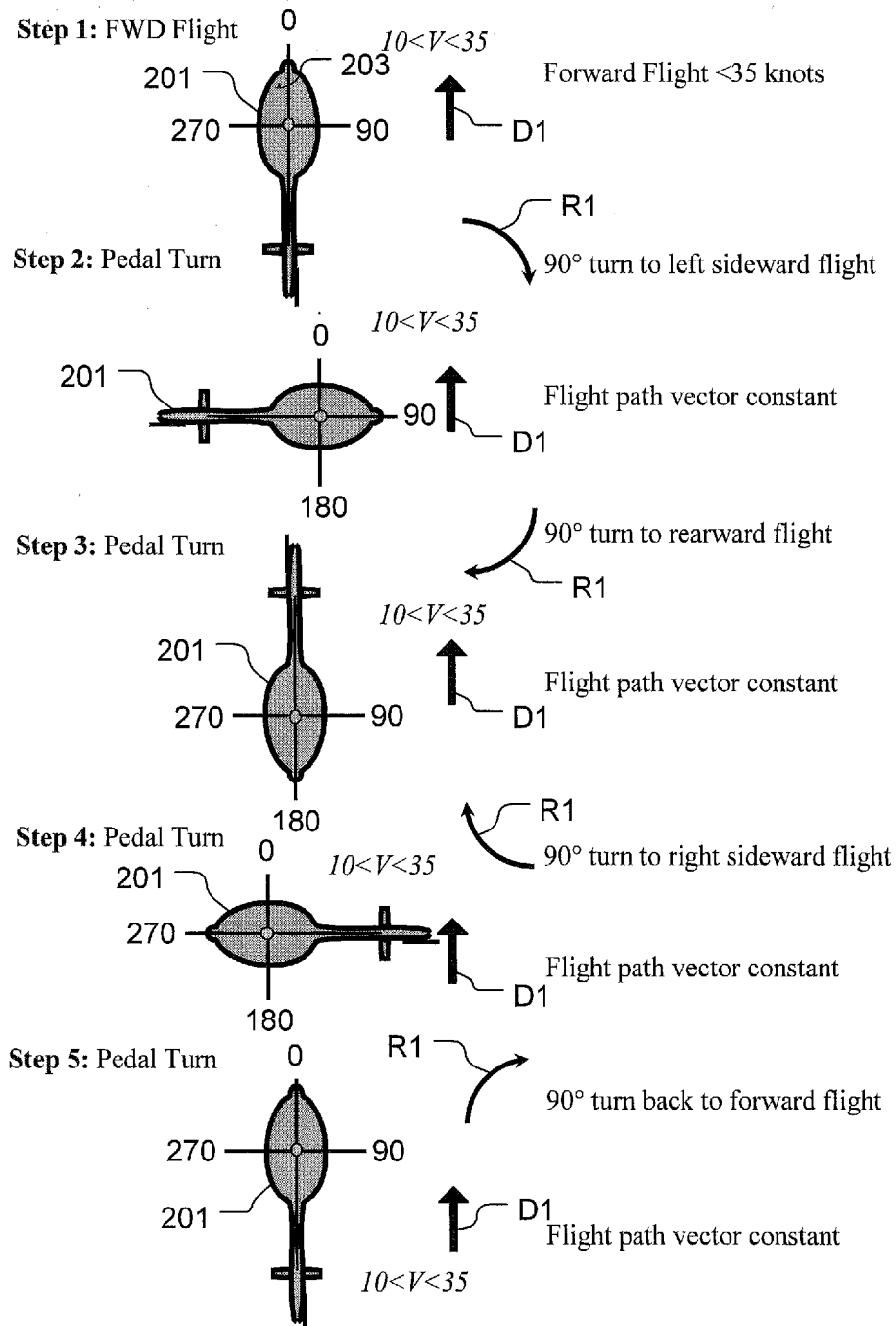
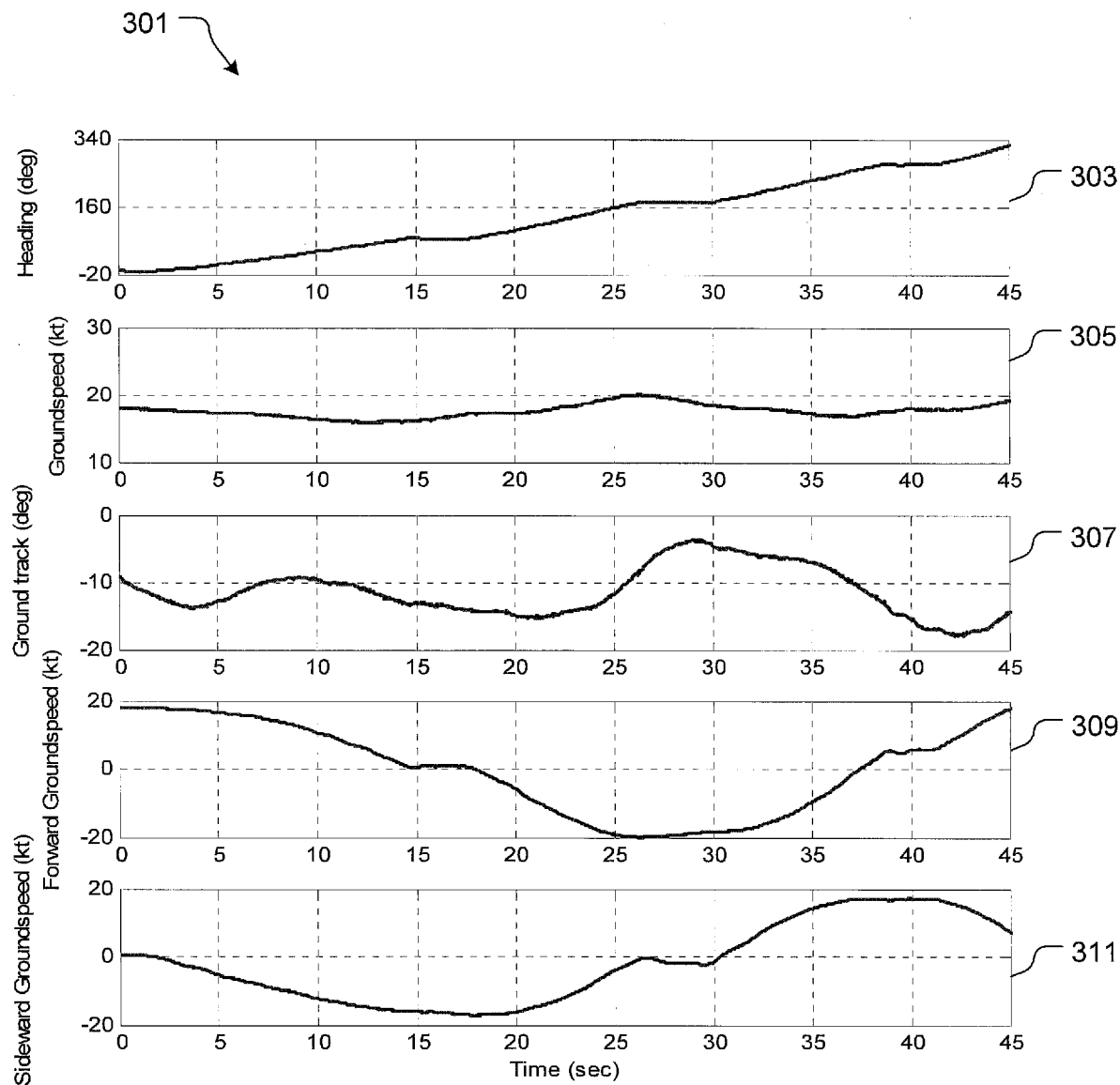


FIG. 2

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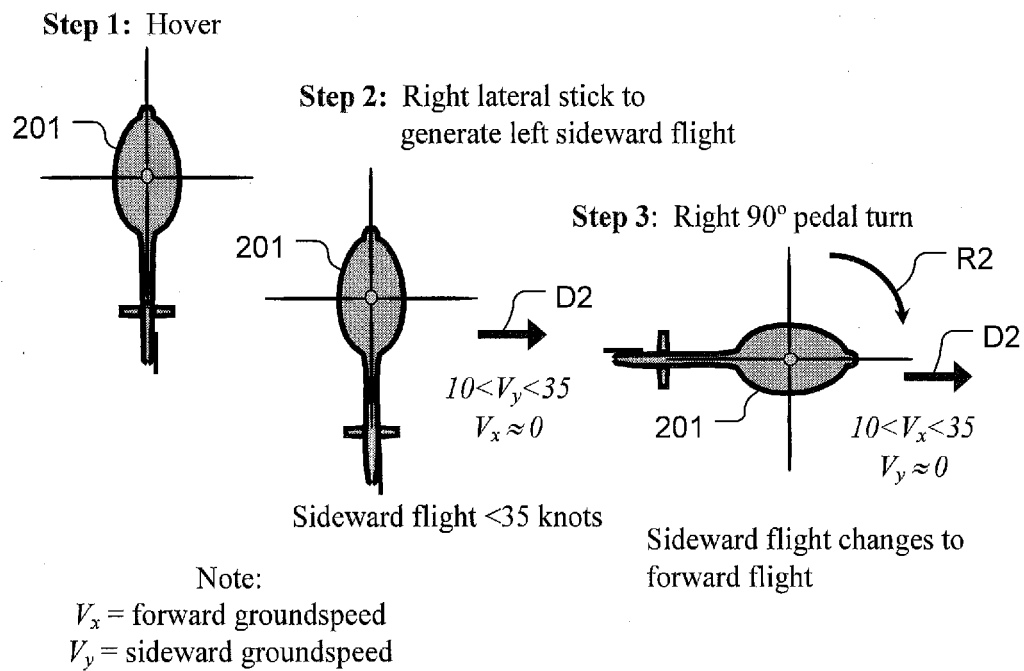


FIG. 4

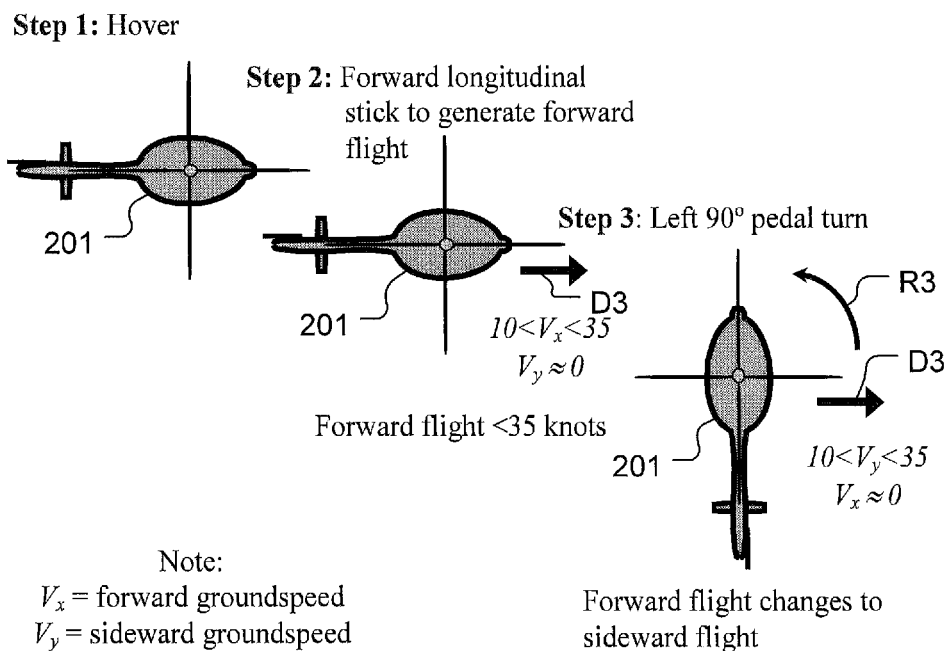
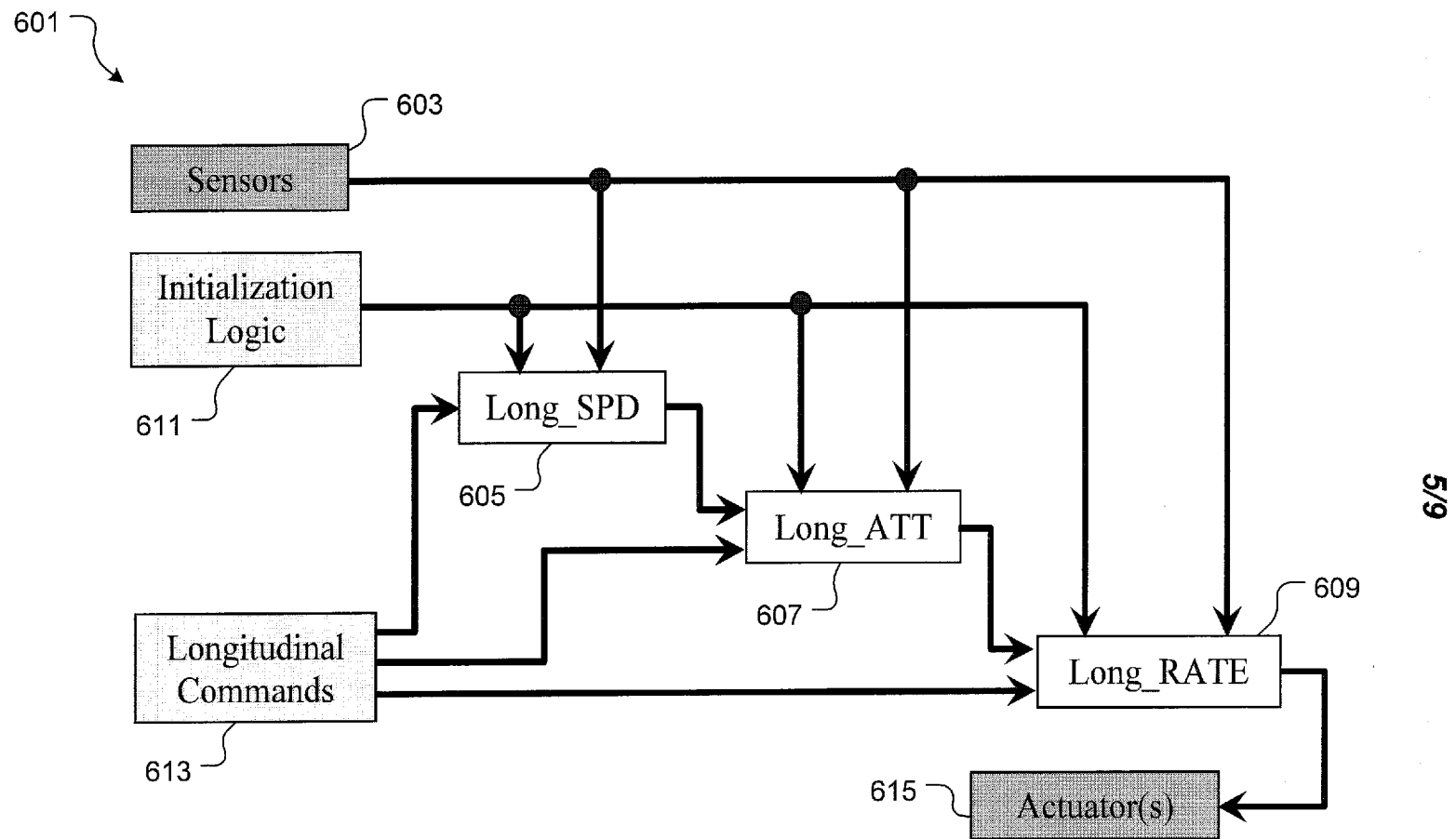
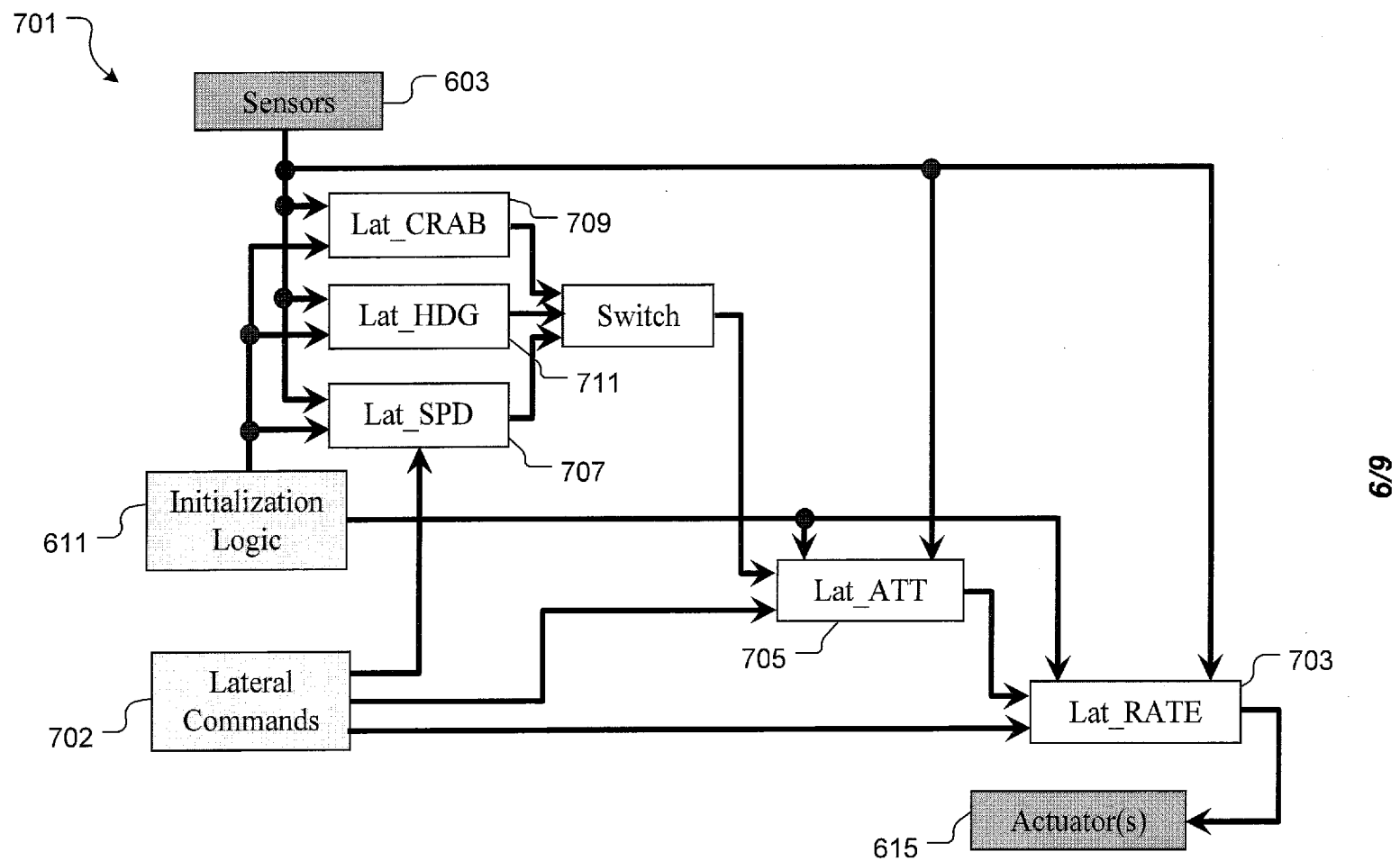


FIG. 5

**FIG. 6**



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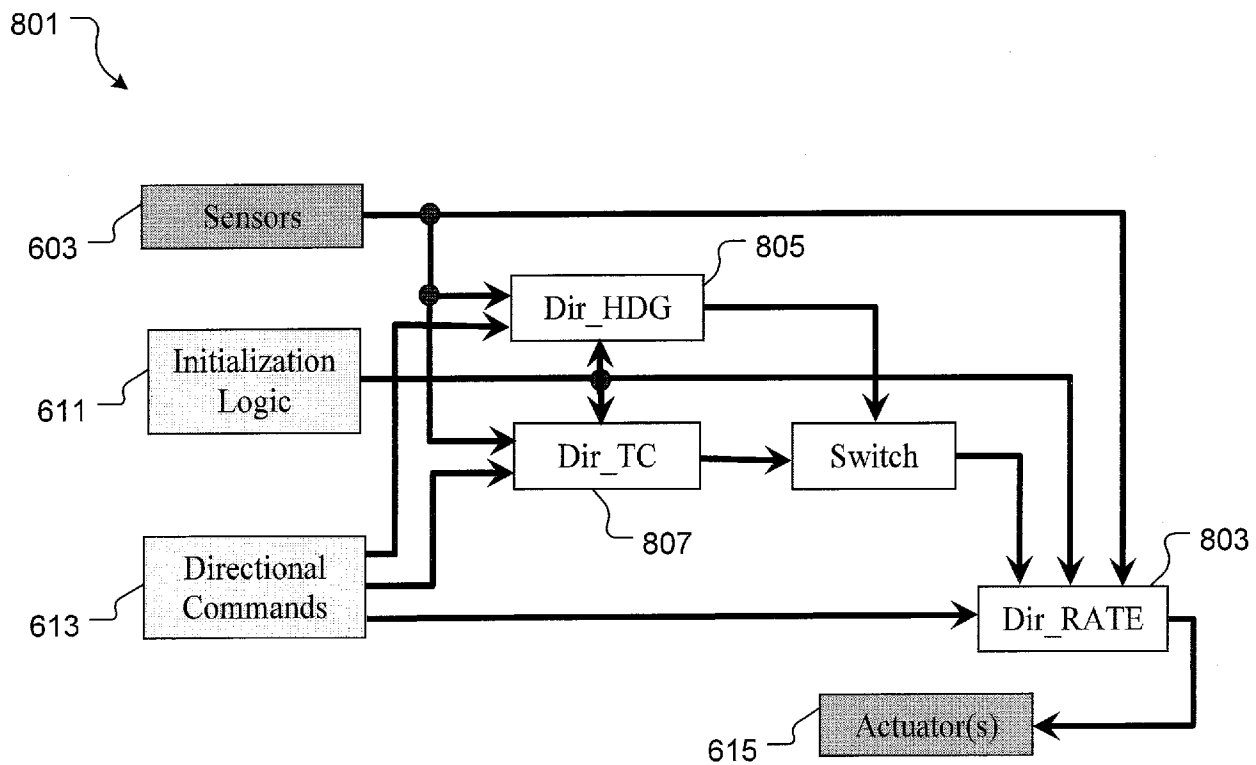


FIG. 8

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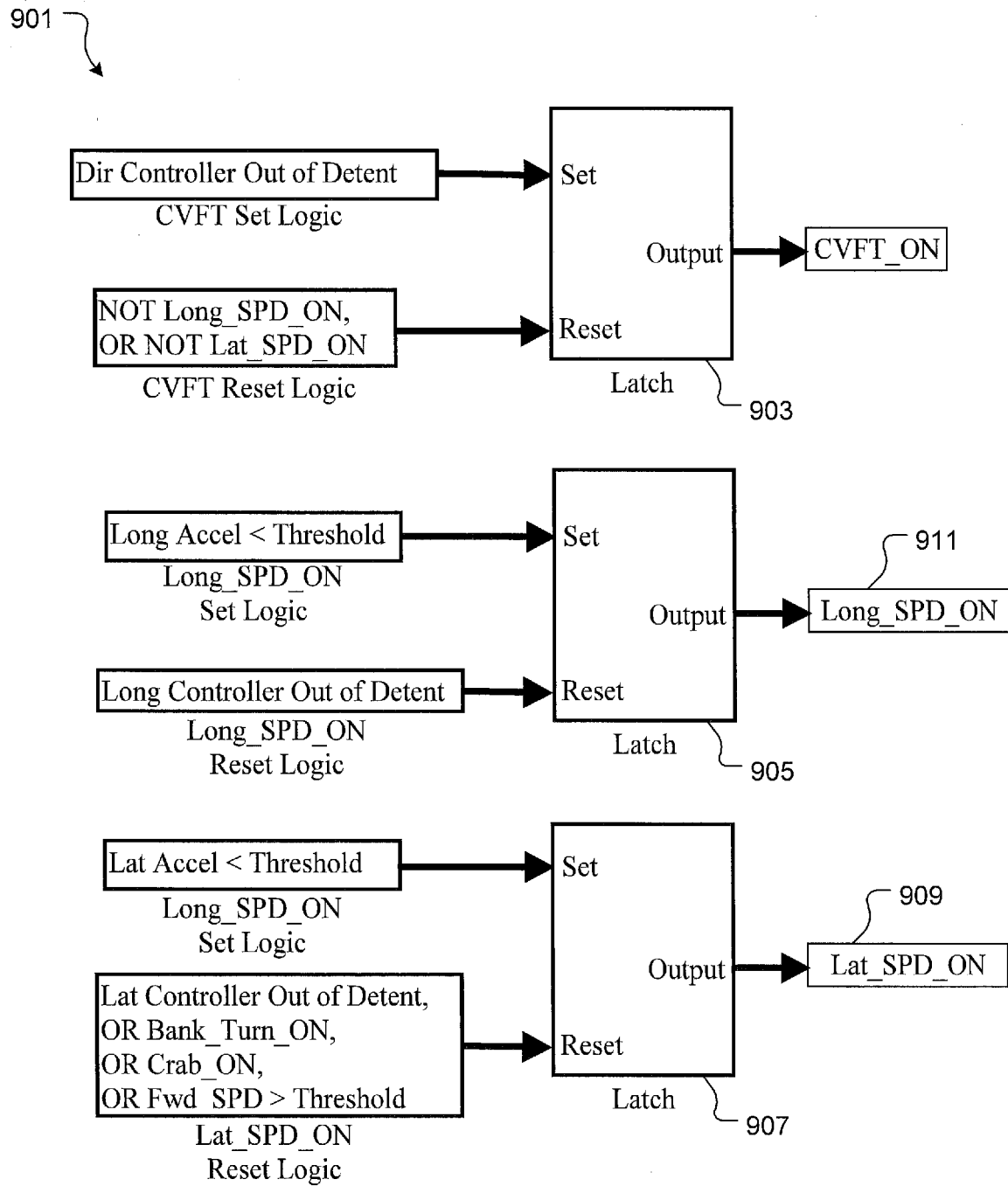


FIG. 9

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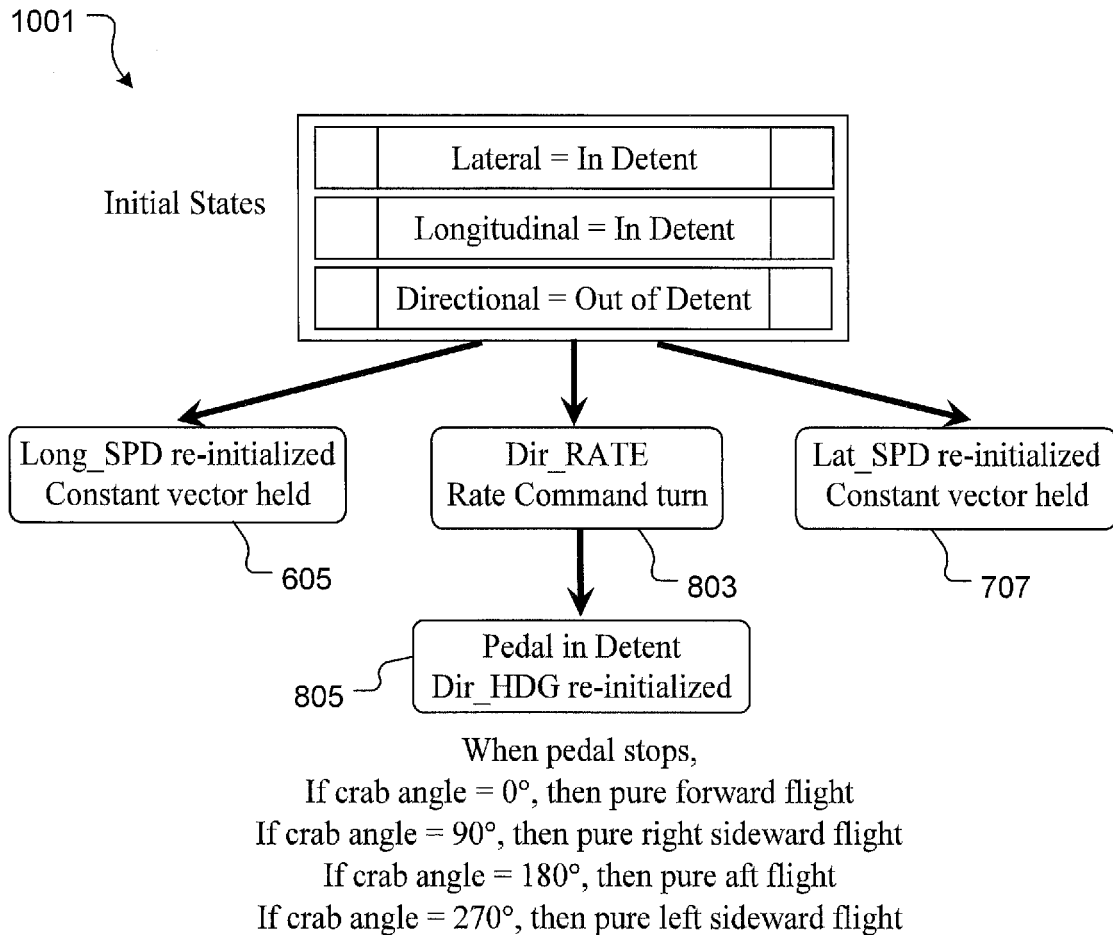


FIG. 10

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FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Technical Field

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.

Description of the Prior Art

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.

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.

An example velocity command system is described in US 5553812, in which an aircraft flight path referenced velocities are determined with respect to an inertial frame of reference, the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that the aircraft maintains a fixed inertial referenced flight path regardless of the pointing direction of the aircraft. Velocity control with respect to an inertial frame of reference is accomplished by controlling the aircraft flight path

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based on aircraft body referenced commanded lateral and longitudinal acceleration and based on aircraft body referenced lateral and longitudinal centrifugal acceleration. Operation in the velocity stabilization mode is provided in response to the manual activation of the velocity stabilization mode by the pilot, provided that the aircraft is already operating in the ground speed mode and the aircraft is not in a coordinated turn.

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.

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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.

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

Brief Description of the Drawings

The novel features believed characteristic of the application are set forth in the appended claims. However, the application itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood with 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;

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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;

5 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

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

Description of the Preferred Embodiment

15 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. As a result of this auto-moding logic, the

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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.

The auto-moding logic 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.

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.

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.

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

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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.

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.

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.

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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 pedal turn is applied to rotate aircraft 201 in a forward heading with a pedal 203. In the preferred embodiment, pedal 203 is a pedal 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 pedal 203. For purposes of this invention, a lateral controller, longitudinal controller, and directional controller are characterized as pedal 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.

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 pedal turn is applied to rotate aircraft 201 such that the forward flight of aircraft 201 changes to a sideward flight heading.

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

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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.

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.

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 a minimum, thus stabilizing the system.

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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-initialize inactive loops in order to eliminate control jumps when switching between the loops to provide seamless and transient free mode changes.

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.

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.

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,

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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).

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".

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.

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

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

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.

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

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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).

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"

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.

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.

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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.

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.

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:

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

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

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.

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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.

Both longitudinal speed hold 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).

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

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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.

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Claims

1. An aircraft (201), comprising:

a sensor (603) carried by the aircraft (201), the sensor (603) being adapted to sense a directional movement (R1) of the aircraft (201);

5 an actuator (615) carried by the aircraft (201), the actuator (615) being utilized to control the directional movement (R1) of the aircraft (201); and

a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system having:

10 a model adapted to decouple the directional movement (R1) 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 (201), the lateral control architecture comprising:

15 a lateral sideward groundspeed control loop (707);

a lateral roll attitude control loop (705); and

a lateral roll rate control loop (703);

20 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 (201); and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

25 wherein the initialization command logic (611) selectively activates the lateral control architecture for controlling the lateral motion of the aircraft (201) and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft (201); and

wherein the control system (601) utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading

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across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

2. The aircraft of claim 1, the aircraft (201) further comprising:

a directional controller, the directional controller being manipulated by a pilot controlling the aircraft (201), the directional controller being in data communication with the control system (601).

3. The aircraft of claim 2, the directional control architecture comprising:

a directional heading control loop (805);
a directional turn coordination control loop (807); and
a directional yaw rate control loop (803).

4. The aircraft of claim 2, further comprising:

a directional control latch (903) in data communication with the directional control architecture;

wherein, as the directional controller is moved out of a detent position, the directional control latch (903) activates a constant vector flat turn motion.

5. The aircraft of claim 1, further comprising:

a lateral controller carried by the aircraft (201), the lateral controller being manipulated by a pilot controlling the aircraft (201), the lateral controller creating a lateral command (702) in data communication with the lateral sideward groundspeed control loop (707), the lateral roll attitude control loop (705), and the lateral roll rate control loop (703).

6. The aircraft of claim 5, further comprising:

a lateral control latch (907) in data communication with the control system (601);
wherein, as the lateral controller is moved out of a detent position, the lateral control latch (907) resets a lateral speed hold (909).

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7. The aircraft of claim 1, the longitudinal control architecture comprising:
a longitudinal forward speed control loop (605);
a longitudinal pitch angle control loop (607); and
a longitudinal pitch rate control loop (609).

5

8. The aircraft of claim 7, the longitudinal control architecture further comprising:
a longitudinal controller carried by the aircraft (201), the longitudinal controller
being manipulated by a pilot controlling the aircraft (201), the longitudinal controller
creating a longitudinal command (613) in data communication with the longitudinal
forward speed control loop (605), the longitudinal pitch angle control loop (607), and the
longitudinal pitch rate control loop (609).

10

9. The aircraft of claim 8, further comprising:
a longitudinal control latch (905) in data communication with the control system
(601);
wherein, as the longitudinal controller is moved out of a detent position, the
longitudinal control latch (905) resets a longitudinal speed hold (911).

15

10. A method to control flat yawing turns of an aircraft (201) while maintaining a
constant vector heading across a ground surface, the method comprising:

20

sensing a directional movement of the aircraft (201) with a sensor (603) carried
by the aircraft (201), the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

controlling the directional movement of the aircraft (201) with an actuator (615)
operably associated with the aircraft (201);

25

providing a control system (601) in data communication with the aircraft sensor
(603) and operably associated with the actuator (615), the control system (601) having:

a model;

a lateral control architecture in data communication with the model, the
lateral control architecture comprising:

30

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a lateral sideward groundspeed control loop (707);

a lateral roll attitude control loop (705); and

a lateral roll rate control loop;

a longitudinal control architecture in data communication with the model;

5 and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

10 decoupling the directional movement of the aircraft (201) 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;

15 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 (611);

20 wherein the control system (601) receives sensed directional movement data from the sensor (603) and operably controls the actuators (615), thus maintaining a constant vector across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

11. The method of claim 10, the method further comprising:

25 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft (201), the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system (601).

30 12. The method of claim 11, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop (805);

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communicating data through a directional turn coordination control loop (807);

and

communicating data through a directional yaw rate control loop (803).

5 13. The method of claim 11, further comprising:
 activating the constant vector flat turn with a directional control latch (903) as the
 directional controller is moved out of a detent position, the directional control latch (903)
 being operably associated with the directional control architecture.

10 14. The method of claim 10 wherein controlling the lateral direction of motion with the
 lateral control architecture comprises:

 communicating lateral motion data through a lateral sideward groundspeed
 control loop (707);

15 communicating lateral motion data through a lateral roll attitude control loop
 (705); and

 communicating lateral motion data through a lateral roll rate control loop (703).

15. The method of claim 10, further comprising:

20 controlling the lateral direction of motion with a lateral controller manipulated by a
 pilot controlling the aircraft (201), the lateral controller being operably associated with
 the lateral control architecture.

16. The method of claim 15, further comprising:

25 resetting a lateral speed hold (909) with a lateral control hatch (907) as the lateral
 controller is moved out of a detent position, the lateral control hatch (907) being in data
 communication with the lateral control architecture.

17. The method of claim 16, wherein controlling the longitudinal direction of motion
 with the longitudinal control architecture comprises:

30 communicating longitudinal motion data through a longitudinal forward speed
 control loop (605);

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communicating longitudinal motion data through a longitudinal pitch angle control loop (607); and

communicating longitudinal motion data through a longitudinal pitch rate control loop (609).

5

18. The method of claim 10, the longitudinal control architecture further comprising:

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft (201), the longitudinal controller being operably associated with the longitudinal control architecture.

10

19. The method of claim 18, further comprising:

resetting a longitudinal speed hold (911) with a longitudinal control hatch (905) as the longitudinal controller is moved out of a detent position, the longitudinal control hatch (905) being in data communication with the longitudinal control architecture.

15

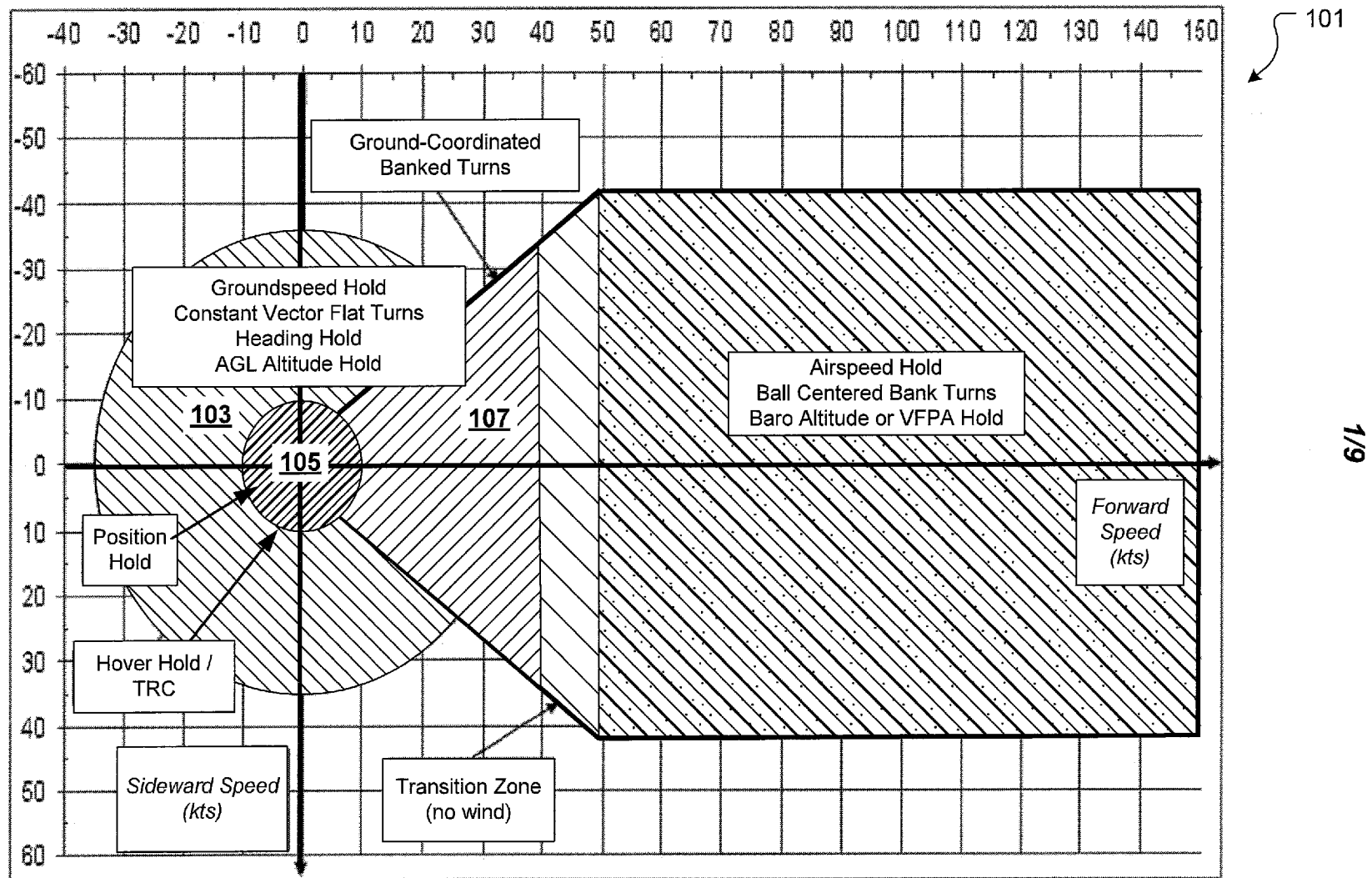


FIG. 1

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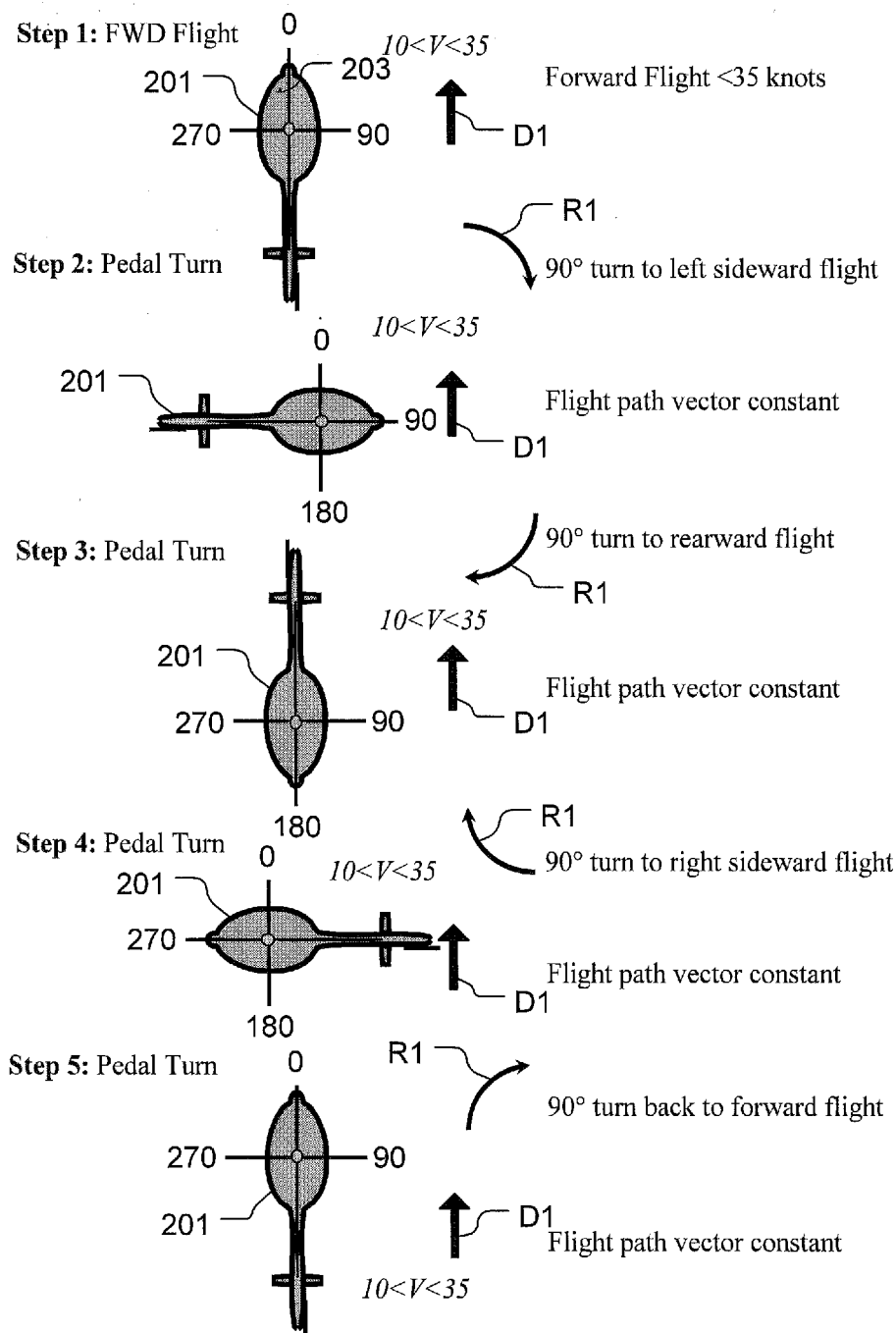
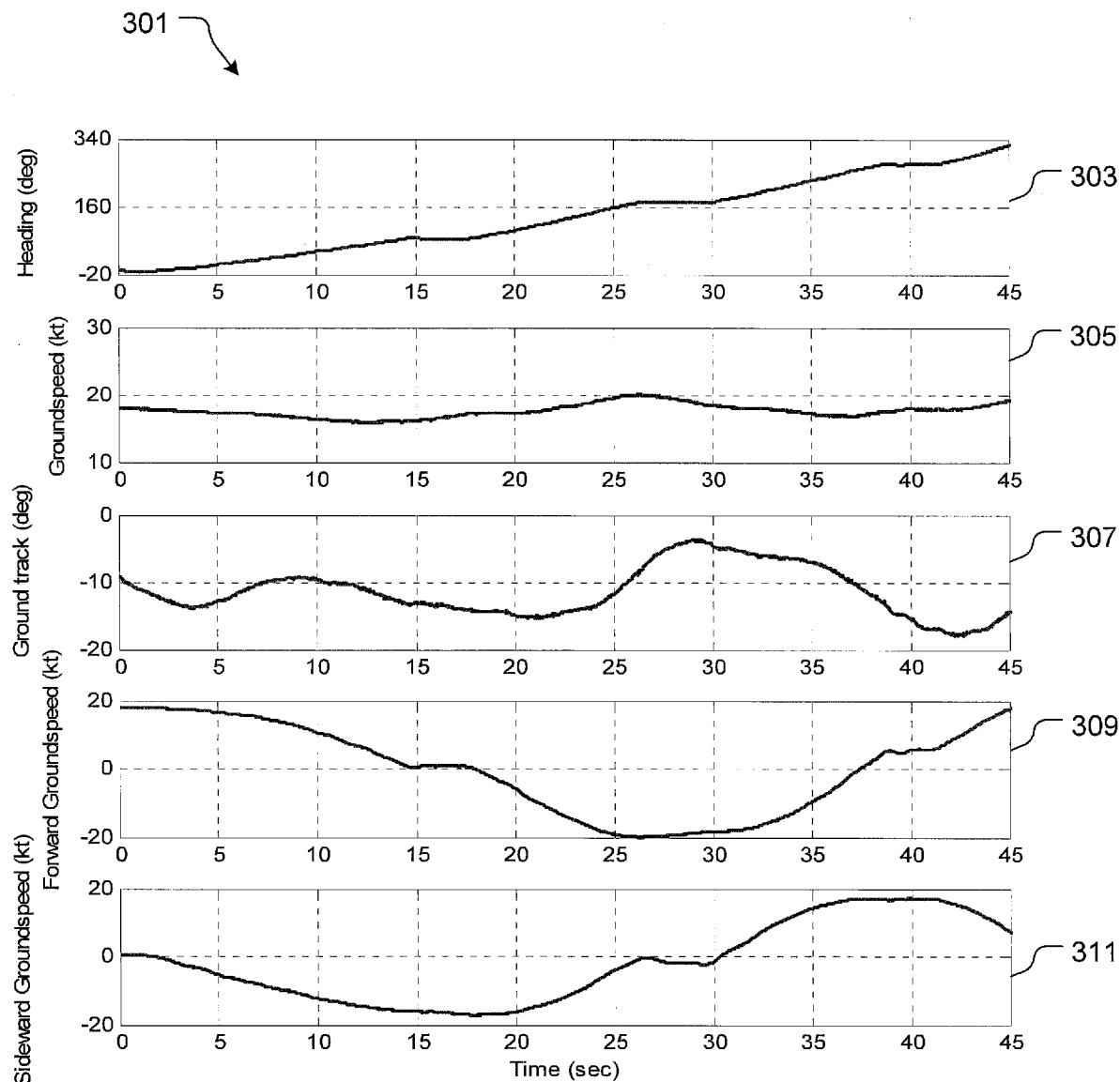


FIG. 2

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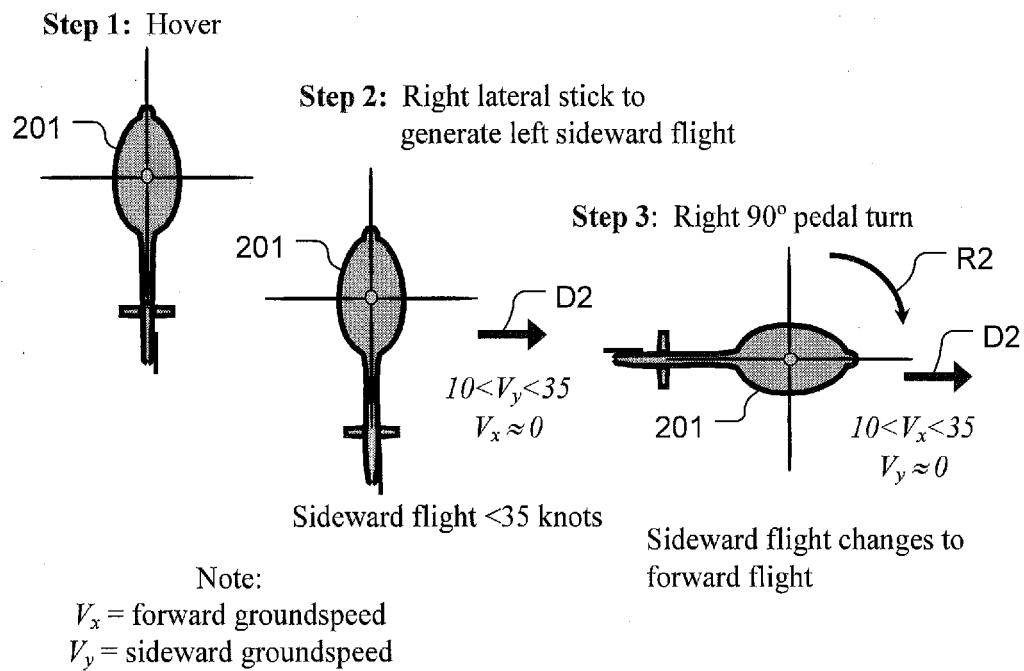


FIG. 4

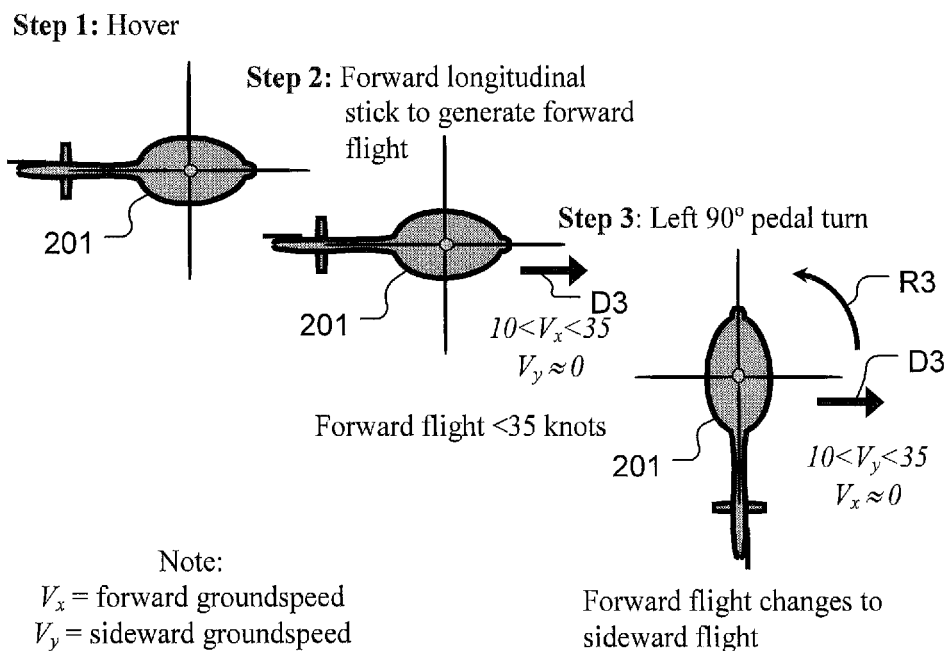
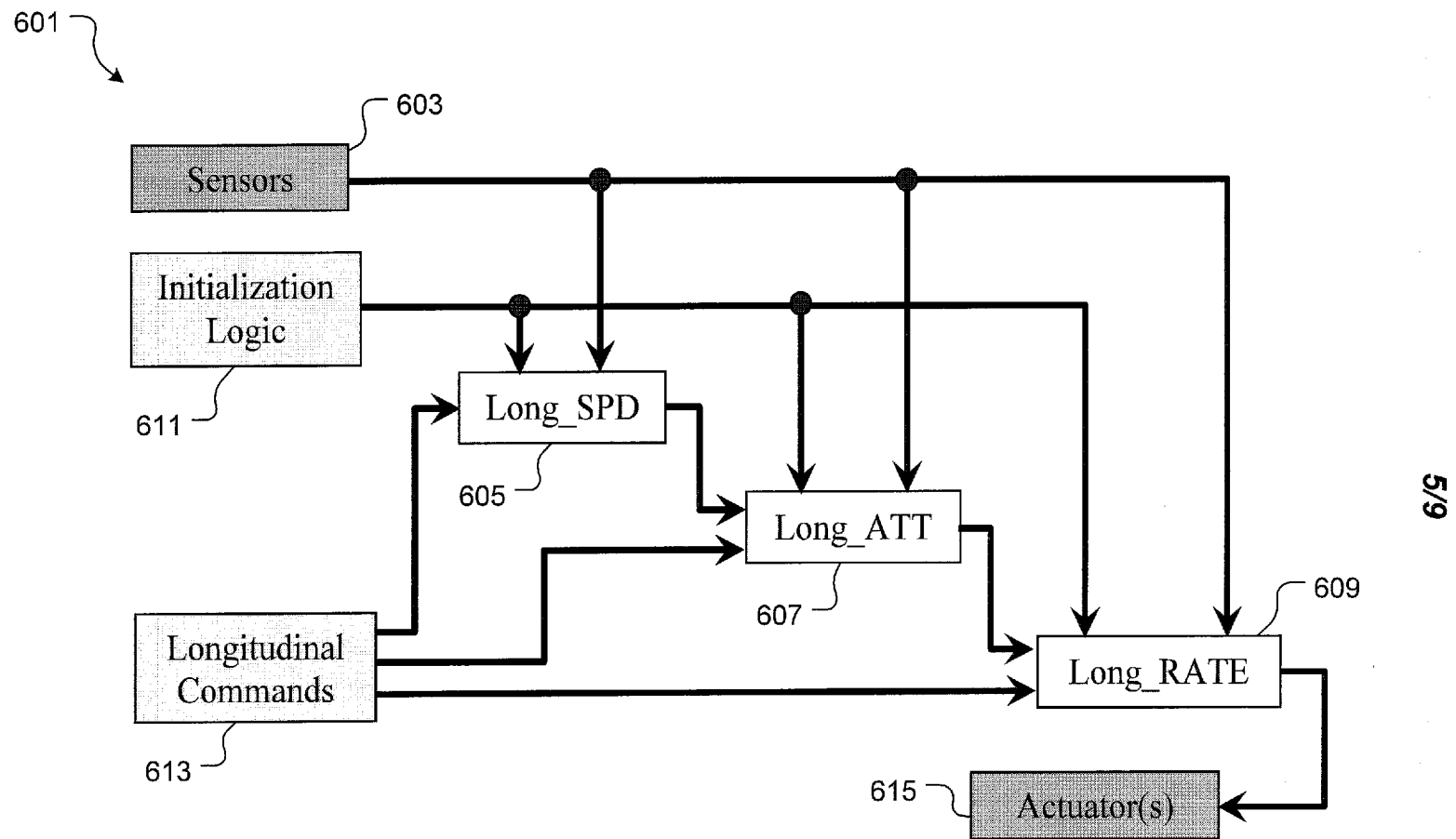
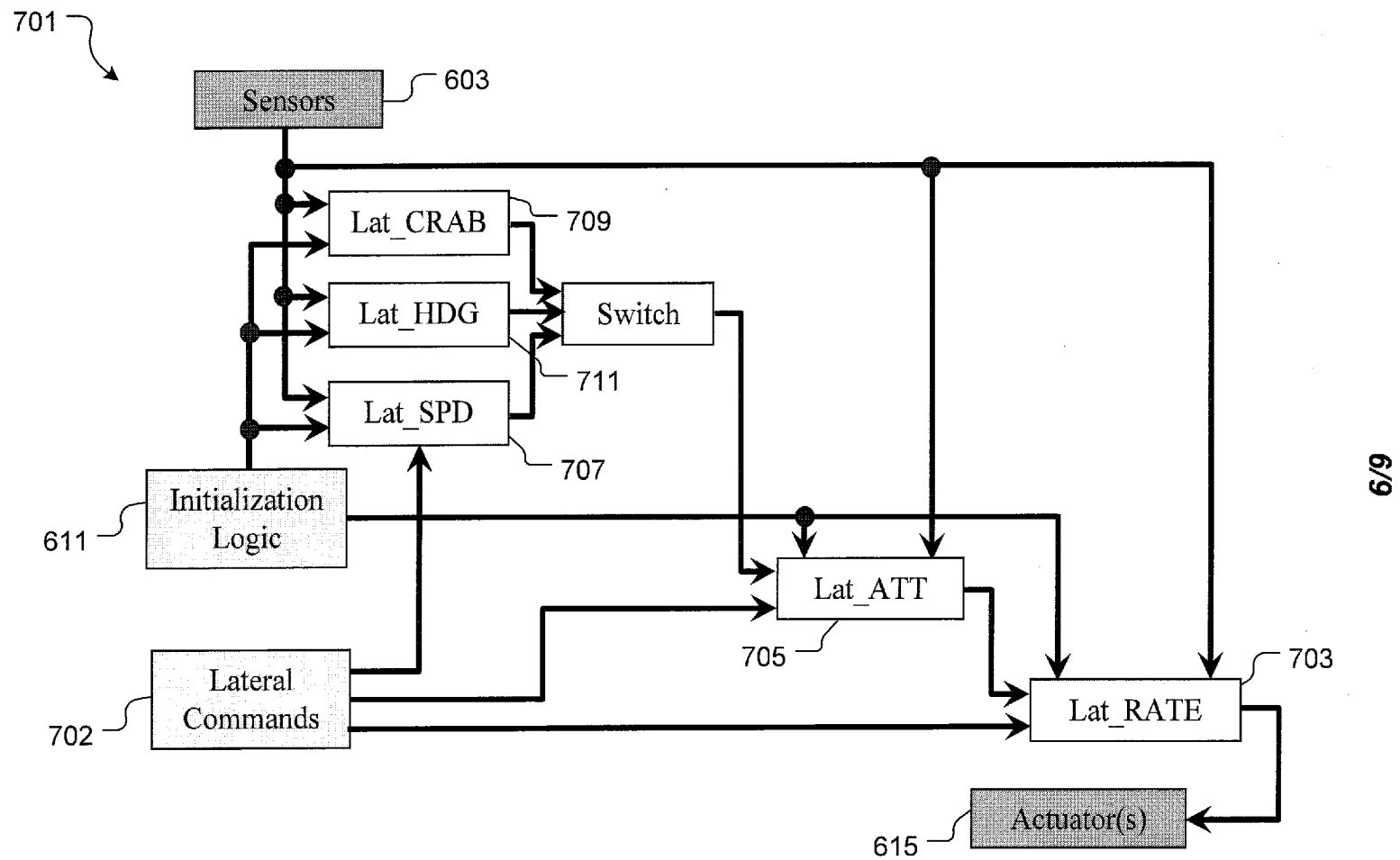


FIG. 5

**FIG. 6**



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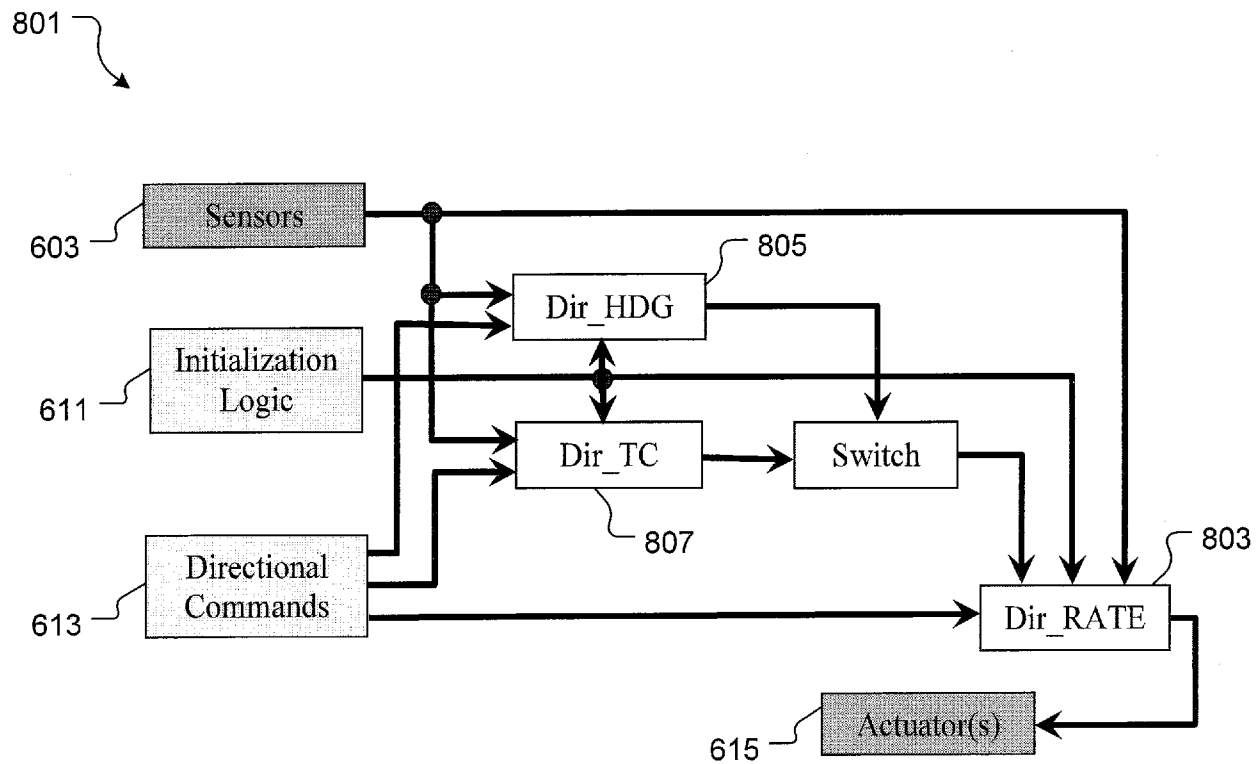


FIG. 8

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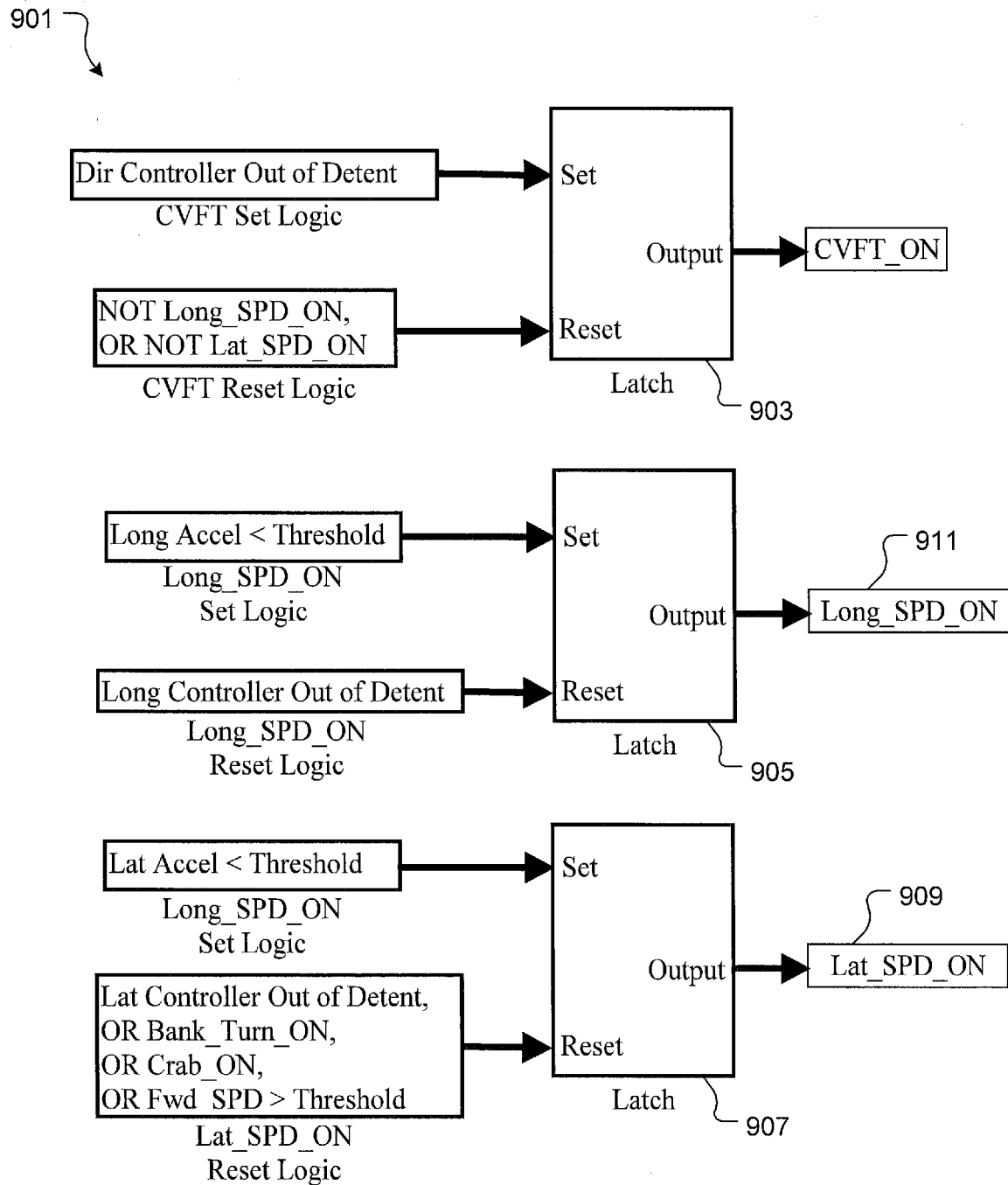


FIG. 9

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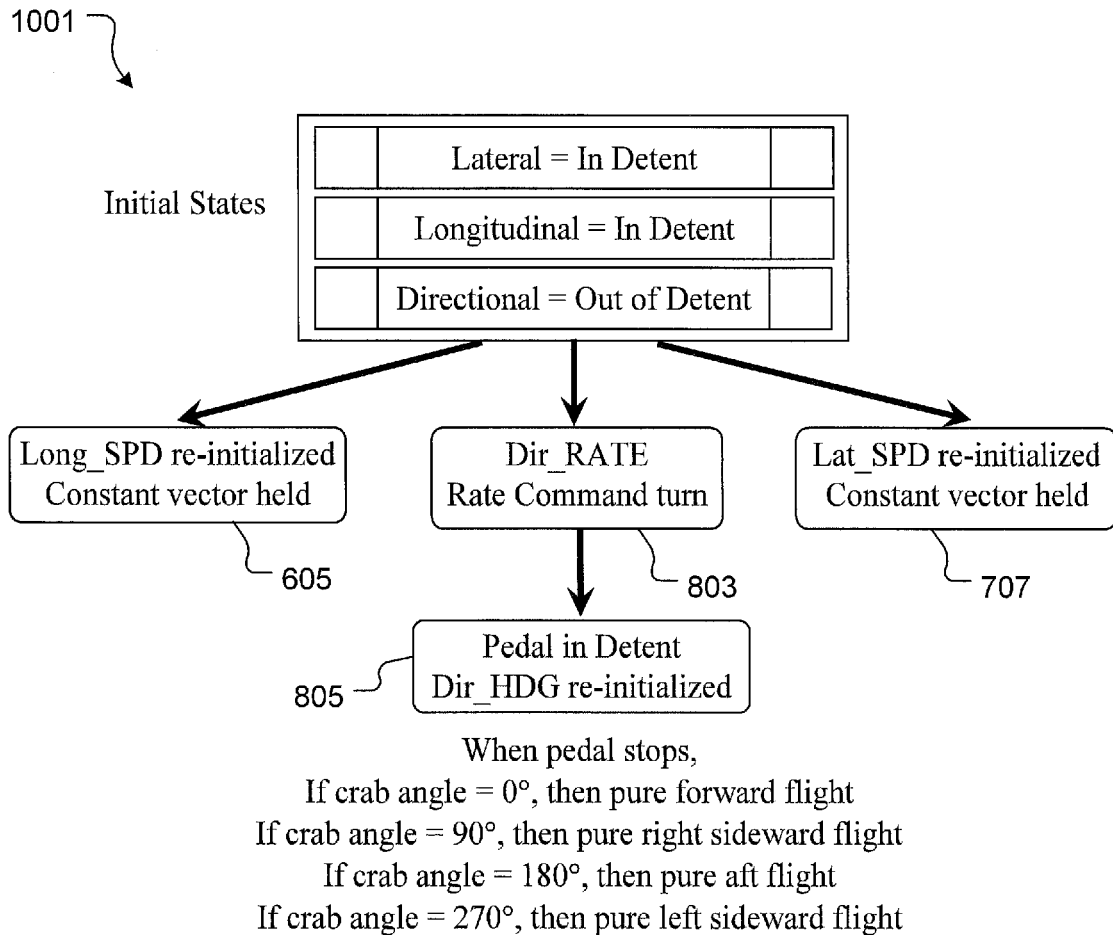


FIG. 10

Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	4147094	
Application number	EP11862189.5	
Date of receipt	24 February 2016	
Receiving Office	European Patent Office, The Hague	
Your reference	JL69579P.EPA	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (1 p.) CLMS-1.pdf\CLMS_JL69579P_230216.pdf (6 p.)	ep-sfd-request.xml EPLETT-1.pdf\D_LTR_EPO_230216.pdf (4 p.) CLMS-HWA-1.pdf\CLMS_JL69579P_230216 trk.pdf (6 p.)
Submitted by	CN=Mark Thurston 27885	
Method of submission	Online	
Date and time receipt generated	24 February 2016, 13:10 (CET)	
Message Digest	E9:D2:00:09:4A:69:B4:44:0D:41:3D:8D:4F:D1:25:FF:0F:9A:1C:09	

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/European Patent Office/

Claims

1. An aircraft (201), comprising:

a sensor (603) carried by the aircraft (201), the sensor (603) being adapted to sense a directional movement (R1) of the aircraft (201);

5 an actuator (615) carried by the aircraft (201), the actuator (615) being utilized to control the directional movement (R1) of the aircraft (201); and

a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system having:

10 a model adapted to decouple the directional movement (R1) 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 (201); the lateral control architecture comprising:

15 a lateral sideward groundspeed control loop (707);

a lateral roll attitude control loop (705); and

a lateral roll rate control loop (703);

20 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 (201); and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

25 wherein the initialization command logic (611) selectively activates the lateral control architecture for controlling the lateral motion of the aircraft (201) and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft (201); and

wherein the control system (601) utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading

across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

2. The aircraft of claim 1, the aircraft (201) further comprising:

a directional controller, the directional controller being manipulated by a pilot controlling the aircraft (201), the directional controller being in data communication with the control system (601).

3. The aircraft of claim 2, the directional control architecture comprising:

a directional heading control loop (805);

a directional turn coordination control loop (807); and

a directional yaw rate control loop (803).

4. The aircraft of claim 2, further comprising:

a directional control latch (903) in data communication with the directional control architecture;

wherein, as the directional controller is moved out of a detent position, the directional control latch (903) activates a constant vector flat turn motion.

~~5. The aircraft of claim 1, the lateral control architecture comprising:~~

~~a lateral sideward groundspeed control loop (707);~~

~~a lateral roll attitude control loop (705); and~~

~~a lateral roll rate control loop (703).~~

56. The aircraft of claim 15, further comprising:

a lateral controller carried by the aircraft (201), the lateral controller being manipulated by a pilot controlling the aircraft (201), the lateral controller creating a lateral command (702) in data communication with the lateral sideward groundspeed control loop (707), the lateral roll attitude control loop (705), and the lateral roll rate control loop (703).

67. The aircraft of claim 56, further comprising:
a lateral control latch (907) in data communication with the control system (601);
wherein, as the lateral controller is moved out of a detent position, the lateral control latch (907) resets a lateral speed hold (909).

5

78. The aircraft of claim 1, the longitudinal control architecture comprising:
a longitudinal forward speed control loop (605);
a longitudinal pitch angle control loop (607); and
a longitudinal pitch rate control loop (609).

10

89. The aircraft of claim 78, the longitudinal control architecture further comprising:
a longitudinal controller carried by the aircraft (201), the longitudinal controller being manipulated by a pilot controlling the aircraft (201), the longitudinal controller creating a longitudinal command (613) in data communication with the longitudinal forward speed control loop (605), the longitudinal pitch angle control loop (607), and the longitudinal pitch rate control loop (609).

15

940. The aircraft of claim 89, further comprising:
a longitudinal control latch (905) in data communication with the control system (601);
wherein, as the longitudinal controller is moved out of a detent position, the longitudinal control latch (905) resets a longitudinal speed hold (911).

20

1044. A method to control flat yawing turns of an aircraft (201) while maintaining a constant vector heading across a ground surface, the method comprising:
sensing a directional movement of the aircraft (201) with a sensor (603) carried by the aircraft (201), the directional movement having:
a longitudinal direction of motion; and
a lateral direction of motion;
controlling the directional movement of the aircraft (201) with an actuator (615) operably associated with the aircraft (201);

25

30

providing a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system (601) having:

a model;

a lateral control architecture in data communication with the model, the

lateral control architecture comprising:

a lateral sideward groundspeed control loop (707);

a lateral roll attitude control loop (705); and

a lateral roll rate control loop;

a longitudinal control architecture in data communication with the model;

and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

decoupling the directional movement of the aircraft (201) 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 (611);

wherein the control system (601) receives sensed directional movement data from the sensor (603) and operably controls the actuators (615), thus maintaining a constant vector across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

1112. The method of claim 1011, the method further comprising:

commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft (201), the directional controller being operably associated

with a directional control architecture, the directional control architecture being in data communication with the control system (601).

5 | 1213. The method of claim 1112, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop (805);
communicating data through a directional turn coordination control loop (807);
and
communicating data through a directional yaw rate control loop (803).

10 | 1314. The method of claim 1112, further comprising:
activating the constant vector flat turn with a directional control latch (903) as the directional controller is moved out of a detent position, the directional control latch (903) being operably associated with the directional control architecture.

15 | 1415. The method of claim 1011 wherein controlling the lateral direction of motion with the lateral control architecture comprises:

communicating lateral motion data through a lateral sideward groundspeed control loop (707);
20 communicating lateral motion data through a lateral roll attitude control loop (705); and
communicating lateral motion data through a lateral roll rate control loop (703).

25 | 1516. The method of claim 1011, further comprising:
controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft (201), the lateral controller being operably associated with the lateral control architecture.

| 1617. The method of claim 1516, further comprising:

resetting a lateral speed hold (909) with a lateral control hatch (907) as the lateral controller is moved out of a detent position, the lateral control hatch (907) being in data communication with the lateral control architecture.

5 | ~~1718~~. The method of claim ~~1617~~, wherein controlling the longitudinal direction of motion with the longitudinal control architecture comprises:

communicating longitudinal motion data through a longitudinal forward speed control loop (605);

10 | communicating longitudinal motion data through a longitudinal pitch angle control loop (607); and

communicating longitudinal motion data through a longitudinal pitch rate control loop (609).

15 | ~~1819~~. The method of claim ~~1011~~, the longitudinal control architecture further comprising:

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft (201), the longitudinal controller being operably associated with the longitudinal control architecture.

20 | ~~1920~~. The method of claim ~~1819~~, further comprising:

resetting a longitudinal speed hold (911) with a longitudinal control hatch (905) as the longitudinal controller is moved out of a detent position, the longitudinal control hatch (905) being in data communication with the longitudinal control architecture.

25

Claims

1. An aircraft (201), comprising:

a sensor (603) carried by the aircraft (201), the sensor (603) being adapted to sense a directional movement (R1) of the aircraft (201);

5 an actuator (615) carried by the aircraft (201), the actuator (615) being utilized to control the directional movement (R1) of the aircraft (201); and

a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system having:

10 a model adapted to decouple the directional movement (R1) 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 (201), the lateral control architecture comprising:

15 a lateral sideward groundspeed control loop (707);
a lateral roll attitude control loop (705); and
a lateral roll rate control loop (703);

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 (201); and

20 an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

25 wherein the initialization command logic (611) selectively activates the lateral control architecture for controlling the lateral motion of the aircraft (201) and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft (201); and

wherein the control system (601) utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading

across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

2. The aircraft of claim 1, the aircraft (201) further comprising:

5 a directional controller, the directional controller being manipulated by a pilot controlling the aircraft (201), the directional controller being in data communication with the control system (601).

3. The aircraft of claim 2, the directional control architecture comprising:

10 a directional heading control loop (805);
a directional turn coordination control loop (807); and
a directional yaw rate control loop (803).

4. The aircraft of claim 2, further comprising:

15 a directional control latch (903) in data communication with the directional control architecture;

wherein, as the directional controller is moved out of a detent position, the directional control latch (903) activates a constant vector flat turn motion.

5. The aircraft of claim 1, further comprising:

20 a lateral controller carried by the aircraft (201), the lateral controller being manipulated by a pilot controlling the aircraft (201), the lateral controller creating a lateral command (702) in data communication with the lateral sideward groundspeed control loop (707), the lateral roll attitude control loop (705), and the lateral roll rate
25 control loop (703).

6. The aircraft of claim 5, further comprising:

30 a lateral control latch (907) in data communication with the control system (601);
wherein, as the lateral controller is moved out of a detent position, the lateral control latch (907) resets a lateral speed hold (909).

7. The aircraft of claim 1, the longitudinal control architecture comprising:
a longitudinal forward speed control loop (605);
a longitudinal pitch angle control loop (607); and
a longitudinal pitch rate control loop (609).

5

8. The aircraft of claim 7, the longitudinal control architecture further comprising:
a longitudinal controller carried by the aircraft (201), the longitudinal controller
being manipulated by a pilot controlling the aircraft (201), the longitudinal controller
creating a longitudinal command (613) in data communication with the longitudinal
forward speed control loop (605), the longitudinal pitch angle control loop (607), and the
longitudinal pitch rate control loop (609).

10

9. The aircraft of claim 8, further comprising:
a longitudinal control latch (905) in data communication with the control system
(601);
wherein, as the longitudinal controller is moved out of a detent position, the
longitudinal control latch (905) resets a longitudinal speed hold (911).

15

10. A method to control flat yawing turns of an aircraft (201) while maintaining a
constant vector heading across a ground surface, the method comprising:

20

sensing a directional movement of the aircraft (201) with a sensor (603) carried
by the aircraft (201), the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

25

controlling the directional movement of the aircraft (201) with an actuator (615)
operably associated with the aircraft (201);

providing a control system (601) in data communication with the aircraft sensor
(603) and operably associated with the actuator (615), the control system (601) having:

a model;

30

a lateral control architecture in data communication with the model, the
lateral control architecture comprising:

a lateral sideward groundspeed control loop (707);

a lateral roll attitude control loop (705); and

a lateral roll rate control loop;

a longitudinal control architecture in data communication with the model;

5 and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

10 decoupling the directional movement of the aircraft (201) 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;

15 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 (611);

20 wherein the control system (601) receives sensed directional movement data from the sensor (603) and operably controls the actuators (615), thus maintaining a constant vector across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

11. The method of claim 10, the method further comprising:

25 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft (201), the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system (601).

30 12. The method of claim 11, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop (805);

communicating data through a directional turn coordination control loop (807);
and
communicating data through a directional yaw rate control loop (803).

5 13. The method of claim 11, further comprising:
 activating the constant vector flat turn with a directional control latch (903) as the
 directional controller is moved out of a detent position, the directional control latch (903)
 being operably associated with the directional control architecture.

10 14. The method of claim 10 wherein controlling the lateral direction of motion with the
 lateral control architecture comprises:
 communicating lateral motion data through a lateral sideward groundspeed
 control loop (707);
 communicating lateral motion data through a lateral roll attitude control loop
15 (705); and
 communicating lateral motion data through a lateral roll rate control loop (703).

 15. The method of claim 10, further comprising:
 controlling the lateral direction of motion with a lateral controller manipulated by a
20 pilot controlling the aircraft (201), the lateral controller being operably associated with
 the lateral control architecture.

 16. The method of claim 15, further comprising:
 resetting a lateral speed hold (909) with a lateral control hatch (907) as the lateral
25 controller is moved out of a detent position, the lateral control hatch (907) being in data
 communication with the lateral control architecture.

 17. The method of claim 16, wherein controlling the longitudinal direction of motion
 with the longitudinal control architecture comprises:
30 communicating longitudinal motion data through a longitudinal forward speed
 control loop (605);

communicating longitudinal motion data through a longitudinal pitch angle control loop (607); and

communicating longitudinal motion data through a longitudinal pitch rate control loop (609).

5

18. The method of claim 10, the longitudinal control architecture further comprising:
controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft (201), the longitudinal controller being operably associated with the longitudinal control architecture.

10

19. The method of claim 18, further comprising:
resetting a longitudinal speed hold (911) with a longitudinal control hatch (905) as the longitudinal controller is moved out of a detent position, the longitudinal control hatch (905) being in data communication with the longitudinal control architecture.

15



Letter accompanying subsequently filed items

Representative:

Mr John Lawrence
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham West Midlands B16 8QQ
United Kingdom

Phone: +44 121 4560000

Fax: +44 121 4561368

E-mail: bham@barkerbrettell.co.uk

80298 Munich

Germany

Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818

NL-2280 HV Rijswijk

Netherlands

Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin

Germany

Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number

11862189.5

Applicant's or representative's reference

JL69579P.EPA

	Description of document	Original file name	Assigned file name
1	Letter relating to the search and examination procedure	D_LTR_EPO_230216.pdf	EPLETT-1.pdf
2	Amended claims (clean copy)	CLMS_JL69579P_230216.pdf	CLMS-1.pdf
3	Amended claims with annotations	CLMS_JL69579P_230216 trk.pdf	CLMS-HWA-1.pdf

Signatures

Place:

Derbyshire, UK

Date:

24 February 2016

Signed by:

Mark Thurston 27885

Representative name:

Dr Mark R. Thurston

Capacity:

(Representative)

JL69579P.EPA

European Patent Office
D-80298 Munchen
Germany

24 February 2016

Online Filing

For the attention of Primary Examiner, H. Pöllmann

Dear Sirs

European Patent Application No. 11862189.5
In the name of Bell Helicopter Textron Inc.
Our ref: JL69579P.EPP/MRT

This is a response to the communication issued pursuant to Article 94(3) EPC dated 23 December 2015.

We enclose an amended set of Claims 1 to 19 on replacement pages 14-19. Please substitute the enclosed claims for those currently on file. For the Examiner's convenience, we further enclose a reference copy of the claims, showing the amendments as tracked changes.

We have amended independent Claim 1 to incorporate the additional subject matter of existing dependent Claim 5. We have also made a corresponding amendment to independent method Claim 10 (formerly Claim 11).

We have consequently deleted existing Claim 5 and have renumbered the remaining claims accordingly.

Thus, we assert that the amendments have basis and do not extend beyond the subject matter of the application in accordance with the requirements of Article 123(2) EPC.

For ease of reference, the following section numbers correspond to those of the Examiner's report.

§1

It is quite clear that the subject matter of amended independent Claim 1 is both novel and inventive over the cited prior art Document D1. Therefore, this claim satisfies the requirements of Articles 54 & 56 EPC.

As amended, Claim 1 recites, inter alia, a "lateral control architecture comprising a lateral sideward groundspeed control loop, a lateral roll attitude control loop and a lateral roll rate control loop", all operably associated with one or more lateral control laws.

Referring to Figure 7 of the present application, reproduced below for the Examiner's convenience, architecture 701 is shown to comprise lateral control laws operably associated with sensors 603, logic 611, lateral commands 702, and actuators 615. The

lateral control laws include the lateral control of roll rate, represented as block 703 "Lat_RATE"; the lateral control of the roll attitude, represented as block 705 "Lat_ATT"; the lateral control of sideward groundspeed, represented as block 707 "Lat_SPD"; the lateral control of the crab angle, represented as block 709 "Lat_CRAB"; and lateral control of heading, represented as block 711 "Lat_HDG".

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, as shown in Figure 7.

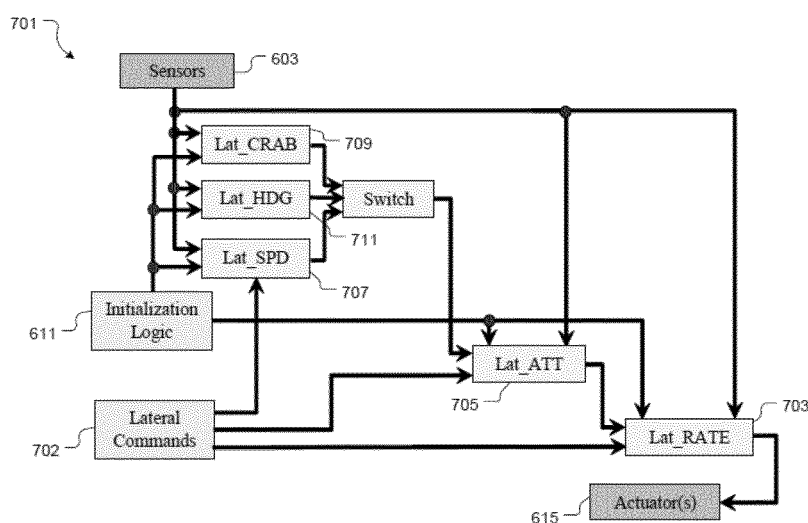


Figure 7.

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

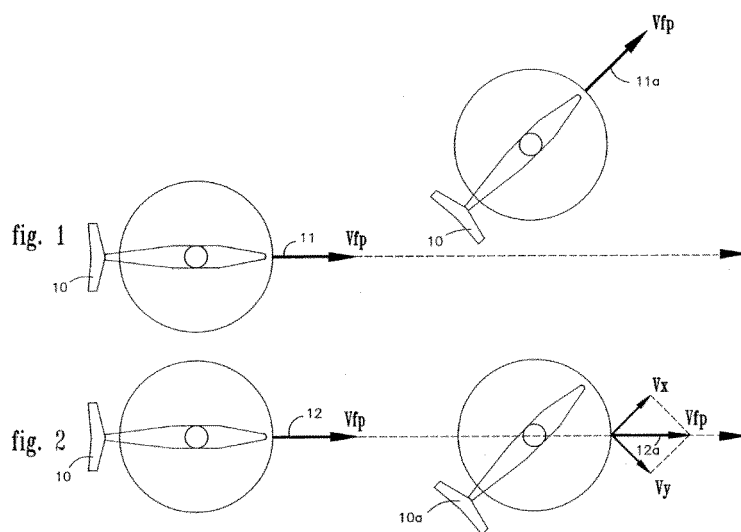
$$\eta = \tan^{-1} \{ V_y / V_x \}$$

where η is the crab angle, V_y is the sideward groundspeed with right positive, and V_x is the forward groundspeed.

When operating in the Ground-Coordinated Banked Turn (GCBT) envelope as shown by region 107 in present 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) – see present description page 9, line 4 through page 10, line 7.

By contrast, although D1 seemingly appears to discuss a method of maintaining a constant vector heading across a ground surface (as asserted by the Examiner), in reality it is evident that there is simply no teaching, or otherwise any prescription, that explains how this functionality is actually achieved in practice.

Instead in D1, although Figures 1 & 2 of the document illustrate the end result of the D1 control system (as shown below) - wherein a constant flight vector is maintained while at a crab angle - there is no teaching as to how this is done.



D1: Figures 1 & 2.

Therefore, we submit again that D1 does not disclose or sufficiently define the steps that are required to achieve this end result, and consequently D1 clearly fails to describe a lateral control architecture comprising the features of amended Claim 1.

Hence, D1 neither anticipates, nor renders obvious, the subject matter of amended Claim 1 and consequently this claim satisfies the requirements of Articles 54 & 56 EPC.

The same or corresponding arguments apply equally or equivalently to the subject matter of amended independent method Claim 10, and therefore this claim is also allowable over the cited art.

§4.1

As provided for in the Guidelines for Examination F-IV 2.3, we have maintained the independent claims in one-part form to avoid a confusing presentation of claim. The Applicant believes that the use of the two-part form would be unsuitable in this case, as the re-arrangement of the features would likely give a distorted or misleading view of the claimed invention and/or prior art.

§4.2

We request that any further amendments to the description be deferred until such time that an allowable subject matter has been agreed upon. Whereupon the Applicant will be more than happy to bring the description into conformity with the claims and to address any outstanding formal and/or clarity issues.

No subject-matter is abandoned by the present amendments and the Applicant reserves the right to reintroduce any subject-matter and/or file divisional applications.

It is submitted that the application is now in condition for allowance. Favourable reconsideration of the application is requested. In the unlikely event that the Examiner is minded to issue as his next action a decision to refuse the application, we hereby request a telephone discussion and/or an informal interview with the Examiner. If the Examiner is minded to refuse the application, we request Oral Proceedings conditional upon that otherwise being the Examiner's intention. This request is made only as a precaution as we expect to make progress on the application via the usual written and telephone channels of communication.

Yours faithfully

Mark R Thurston – Professional Representative
Barker Brettell LLP

Contact: Dr Mark R. Thurston
Email: mark.thurston@barkerbrettell.co.uk

The examination is being carried out on the **following application documents**

Description, Pages

2, 5-12 as published

1, 1a, 3, 4, 13 filed in electronic form on 26-06-2015

Claims, Numbers

1-20 filed in electronic form on 26-06-2015

Drawings, Sheets

1/9-9/9 as published

1 Prior Art

The following document is referred to in this communication:

D1 US 5 553 812 A (GOLD PHILLIP J [US] ET AL) 10 September 1996
(1996-09-10)

2 Objections under Article 52(1) and 54(1,2) EPC (Novelty)

The independent claims 1 and 11 of the present application do not meet the requirements of Article 52(1) EPC because the subject-matter of claims 1 and 11 is not new in the sense of Article 54(1) and (2) EPC.

The applicant added the following feature to the previous independent claims 1 and 11 whose subject-matter was not new (please refer to the communication of 17.02.2015):

maintain (a constant vector heading across a ground surface) while the aircraft flies with a crab angle greater than zero.

However, this feature is disclosed in D1 (Background of the Invention, Disclosure of the Invention; fig. 2). Actually, maintaining a constant vector heading across a ground surface while the aircraft flies with a crab angle greater than zero is the subject-matter of document D1!

Therefore, the subject-matter of independent claims 1 and 11 still is not new (Article 54 EPC).

3 **Remarks**

- 4 It is not at present apparent which part of the application could serve as a basis for a new, allowable claim. Should the applicants nevertheless regard some particular matter as patentable, an independent claim should be filed taking account of Rule 43(1) EPC. The applicants should also indicate in the letter of reply the difference between the subject-matter of the new claim and the state of the art, and the significance thereof. In addition, they should be aware of the objections and formalities as follows:
- 4.1 Independent claims should be drafted in the two-part form. If in the applicant's view the two-part form is not suitable he should give reasons for that in his answer. In addition the applicant should clearly describe which features of the subject-matter of the new claim are already known from document **D1** (see Guidelines, F-IV. 2.2, 2.3).
- 4.2 When filing amended claims the applicant should at the same time bring the description into conformity with the amended claims. Care should be taken during revision, especially in the introductory portion and any statements of problem or advantage should be stated.
- 4.3 In order to facilitate the examination of the conformity of the amended application with the requirements of Article 123(2) EPC, the applicant is requested to clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (Rule 137(4) EPC).



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME-UNI

Formalities Officer
Name: Molloy, Jacinta
Tel: +49 89 2399 - 7581
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Pöllmann, H
Tel: +49 89 2399 - 6017

Application No. 11 862 189.5 - 1802	Ref. JL69579P.EPP	Date 23.12.2015
Applicant Bell Helicopter Textron Inc.		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Pöllmann, H
Primary Examiner
For the Examining Division

Enclosure(s): 2 page/s reasons (Form 2906)

Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	3593093	
Application number	EP11862189.5	
Date of receipt	26 June 2015	
Receiving Office	European Patent Office, The Hague	
Your reference	JL69579P.EPA	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (1 p.) DESC-HWA-1.pdf\DECR_TRK_26061 5.pdf (5 p.) CLMS-HWA-1.pdf\CLMS_TRK_26061 5.pdf (6 p.)	ep-sfd-request.xml EPLETT-1.pdf\LTR_EPO_260615.pdf (3 p.) DESC-1.pdf\DECR_CLN_260615.pdf (5 p.) CLMS-1.pdf\CLMS_CLN_260615.pdf (6 p.)
Submitted by	CN=Mark Thurston 27885	
Method of submission	Online	
Date and time receipt generated	26 June 2015, 15:02 (CEST)	
Message Digest	AB:4F:DA:44:EA:05:D8:42:8E:26:0D:5D:AD:E3:55:05:00:76:9B:45	

Correction by the EPO of errors in debit instructions filed by eOLF

Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

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Claims

1. An aircraft (201), comprising:
- a sensor (603) carried by the aircraft (201), the sensor (603) being adapted to sense a directional movement (R1) of the aircraft (201);
- an actuator (615) carried by the aircraft (201), the actuator (615) being utilized to control the directional movement (R1) of the aircraft (201); and
- a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system having:
- a model adapted to decouple the directional movement (R1) 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 (201);
- 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 (201); and
- an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;
- wherein the initialization command logic (611) selectively activates the lateral control architecture for controlling the lateral motion of the aircraft (201) and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft (201); and
- wherein the control system (601) utilizes the lateral control architecture and the longitudinal control architecture to ~~control a yaw movement of the aircraft while the aircraft maintains~~ maintain a constant vector heading across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

- 15-

2. The aircraft of claim 1, the aircraft (201) further comprising:
a directional controller, the directional controller being manipulated by a pilot
controlling the aircraft (201), the directional controller being in data communication with
the control system (601).

3. The aircraft of claim 2, the directional control architecture comprising:
a directional heading control loop (805);
a directional turn coordination control loop (807); and
a directional yaw rate control loop (803).

4. The aircraft of claim 2, further comprising:
a directional control latch (903) in data communication with the directional control
architecture;

wherein, as the directional controller is moved out of a detent position, the
directional control latch (903) activates a constant vector flat turn motion.

5. The aircraft of claim 1, the lateral control architecture comprising:
a lateral sideward groundspeed control loop (707);
a lateral roll attitude control loop (705); and
a lateral roll rate control loop (703).

6. The aircraft of claim 5, further comprising:
a lateral controller carried by the aircraft (201), the lateral controller being
manipulated by a pilot controlling the aircraft (201), the lateral controller creating a
lateral command (702) in data communication with the lateral sideward groundspeed
control loop (707), the lateral roll attitude control loop (705), and the lateral roll rate
control loop (703).

7. The aircraft of claim 6, further comprising:

a lateral control ~~latch~~ latch (907) in data communication with the control system (601);

wherein, as the lateral controller is moved out of a detent position, the lateral control latch (907) resets a lateral speed hold (909).

8. The aircraft of claim 1, the longitudinal control architecture comprising:

a longitudinal forward speed control loop (605);

a longitudinal pitch angle control loop (607); and

a longitudinal pitch rate control loop (609).

9. The aircraft of claim 8, the longitudinal control architecture further comprising:

a longitudinal controller carried by the aircraft (201), the longitudinal controller being manipulated by a pilot controlling the aircraft (201), the longitudinal controller creating a longitudinal command (613) in data communication with the longitudinal forward speed control loop (605), the longitudinal pitch angle control loop (607), and the longitudinal pitch rate control loop (609).

10. The aircraft of claim 9, further comprising:

a longitudinal control ~~latch~~ latch (905) in data communication with the control system (601);

wherein, as the longitudinal controller is moved out of a detent position, the longitudinal control latch (905) resets a longitudinal speed hold (911).

11. A method to control flat yawing turns of an aircraft (201) while maintaining a constant vector heading across a ground surface, the method comprising:

sensing a directional movement of the aircraft (201) with a sensor (603) carried by the aircraft (201), the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

- 17 -

controlling the directional movement of the aircraft (201) with an actuator (615) operably associated with the aircraft (201);

providing a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system (601) having:

a model;

a lateral control architecture in data communication with the model;

a longitudinal control architecture in data communication with the model;

and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

decoupling the directional movement of the aircraft (201) 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 (611);

wherein the control system (601) receives sensed directional movement data from the sensor (603) and operably controls the actuators (615), thus providing selective control of the yawing turns of the aircraft while maintaining a constant vector across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

12. The method of claim 11, the method further comprising:

commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft (201), the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system (601).

- 18-

13. The method of claim 12, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop (805);
communicating data through a directional turn coordination control loop (807);
and
communicating data through a directional yaw rate control loop (803).

14. The method of claim 12, further comprising:

activating the constant vector flat turn with a directional control latch (903) as the directional controller is moved out of a detent position, the directional control latch (903) being operably associated with the directional control architecture.

15. The method of claim 11 wherein controlling the lateral direction of motion with the ~~or a~~ lateral control architecture comprises:

communicating lateral motion data through a lateral sideward groundspeed control loop (707);
communicating lateral motion data through a lateral roll attitude control loop (705); and
communicating lateral motion data through a lateral roll rate control loop (703).

16. The method of claim 11, further comprising:

controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft (201), the lateral controller being operably associated with the ~~or a~~ lateral control architecture.

17. The method of claim 16, further comprising:

resetting a lateral speed hold (909) with a lateral control hatch (907) as the lateral controller is moved out of a detent position, the lateral control hatch (907) being in data communication with the lateral control architecture.

- 19-

18. The method of claim 17, wherein controlling the longitudinal direction of motion with the ~~or a~~ longitudinal control architecture comprises:

communicating longitudinal motion data through a longitudinal forward speed control loop (605);

communicating longitudinal motion data through a longitudinal pitch angle control loop (607); and

communicating longitudinal motion data through a longitudinal pitch rate control loop (609).

19. The method of claim 11, the longitudinal control architecture further comprising: controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft (201), the longitudinal controller being operably associated with the longitudinal control architecture.

20. The method of claim 19, further comprising: resetting a longitudinal speed hold (911) with a longitudinal control hatch (905) as the longitudinal controller is moved out of a detent position, the longitudinal control hatch (905) being in data communication with the longitudinal control architecture.

FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Technical Field

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.

Description of the Prior Art

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.

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.

An example velocity command system is described in US 5553812, in which an aircraft flight path referenced velocities are determined with respect to an inertial frame of reference, the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that the aircraft maintains a fixed inertial referenced flight path regardless of the pointing direction of the aircraft. Velocity control with respect to an inertial frame of reference is accomplished by controlling the aircraft flight path

5 | based on aircraft body referenced commanded lateral and longitudinal acceleration and
based on aircraft body referenced lateral and longitudinal centrifugal acceleration.
Operation in the velocity stabilization mode is provided in response to the manual
activation of the velocity stabilization mode by the pilot, provided that the aircraft is
already operating in the ground speed mode and the aircraft is not in a coordinated turn.

10 | 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.

- 3 -

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;

5 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

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

15 ~~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.~~

Description of the Preferred Embodiment

20 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. As a result of this auto-moding logic, the

- 4 -

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.

5 The auto-moding logic 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
10 having to use cockpit switches to change modes.

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
15 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.

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
20 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
25 with control systems of different types of aircraft, both manned and unmanned.

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

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.

5 ~~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
10 ~~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.~~

Claims

1. An aircraft (201), comprising:

a sensor (603) carried by the aircraft (201), the sensor (603) being adapted to sense a directional movement (R1) of the aircraft (201);

5 an actuator (615) carried by the aircraft (201), the actuator (615) being utilized to control the directional movement (R1) of the aircraft (201); and

a control system (601) in data communication with the aircraft sensor (603) and operably associated with the actuator (615), the control system having:

10 a model adapted to decouple the directional movement (R1) 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 (201);

15 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 (201); and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

20 wherein the initialization command logic (611) selectively activates the lateral control architecture for controlling the lateral motion of the aircraft (201) and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft (201); and

25 wherein the control system (601) utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

2. The aircraft of claim 1, the aircraft (201) further comprising:

a directional controller, the directional controller being manipulated by a pilot controlling the aircraft (201), the directional controller being in data communication with the control system (601).

- 5 3. The aircraft of claim 2, the directional control architecture comprising:
 a directional heading control loop (805);
 a directional turn coordination control loop (807); and
 a directional yaw rate control loop (803).

- 10 4. The aircraft of claim 2, further comprising:
 a directional control latch (903) in data communication with the directional control
 architecture;
 wherein, as the directional controller is moved out of a detent position, the
 directional control latch (903) activates a constant vector flat turn motion.

- 15 5. The aircraft of claim 1, the lateral control architecture comprising:
 a lateral sideward groundspeed control loop (707);
 a lateral roll attitude control loop (705); and
 a lateral roll rate control loop (703).

- 20 6. The aircraft of claim 5, further comprising:
 a lateral controller carried by the aircraft (201), the lateral controller being
 manipulated by a pilot controlling the aircraft (201), the lateral controller creating a
 lateral command (702) in data communication with the lateral sideward groundspeed
25 control loop (707), the lateral roll attitude control loop (705), and the lateral roll rate
 control loop (703).

7. The aircraft of claim 6, further comprising:
 a lateral control latch (907) in data communication with the control system (601);
30 wherein, as the lateral controller is moved out of a detent position, the lateral
 control latch (907) resets a lateral speed hold (909).

8. The aircraft of claim 1, the longitudinal control architecture comprising:
a longitudinal forward speed control loop (605);
a longitudinal pitch angle control loop (607); and
a longitudinal pitch rate control loop (609).

5

9. The aircraft of claim 8, the longitudinal control architecture further comprising:
a longitudinal controller carried by the aircraft (201), the longitudinal controller
being manipulated by a pilot controlling the aircraft (201), the longitudinal controller
creating a longitudinal command (613) in data communication with the longitudinal
forward speed control loop (605), the longitudinal pitch angle control loop (607), and the
longitudinal pitch rate control loop (609).

10

10. The aircraft of claim 9, further comprising:
a longitudinal control latch (905) in data communication with the control system
(601);
wherein, as the longitudinal controller is moved out of a detent position, the
longitudinal control latch (905) resets a longitudinal speed hold (911).

15

11. A method to control flat yawing turns of an aircraft (201) while maintaining a
constant vector heading across a ground surface, the method comprising:
sensing a directional movement of the aircraft (201) with a sensor (603) carried
by the aircraft (201), the directional movement having:

20

- a longitudinal direction of motion; and
- a lateral direction of motion;

25

- controlling the directional movement of the aircraft (201) with an actuator (615)
operably associated with the aircraft (201);

- providing a control system (601) in data communication with the aircraft sensor
(603) and operably associated with the actuator (615), the control system (601) having:

- a model;
- a lateral control architecture in data communication with the model;
- a longitudinal control architecture in data communication with the model;

30

and

an initialization command logic (611) in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

5 decoupling the directional movement of the aircraft (201) 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;

10 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 (611);

15 wherein the control system (601) receives sensed directional movement data from the sensor (603) and operably controls the actuators (615), thus maintaining a constant vector across a ground surface while the aircraft (201) flies with a crab angle greater than zero.

12. The method of claim 11, the method further comprising:

20 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft (201), the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system (601).

25 13. The method of claim 12, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop (805);

communicating data through a directional turn coordination control loop (807);

and

30 communicating data through a directional yaw rate control loop (803).

14. The method of claim 12, further comprising:
activating the constant vector flat turn with a directional control latch (903) as the directional controller is moved out of a detent position, the directional control latch (903) being operably associated with the directional control architecture.

5

15. The method of claim 11 wherein controlling the lateral direction of motion with the lateral control architecture comprises:

communicating lateral motion data through a lateral sideward groundspeed control loop (707);

10

communicating lateral motion data through a lateral roll attitude control loop (705); and

communicating lateral motion data through a lateral roll rate control loop (703).

16. The method of claim 11, further comprising:

15

controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft (201), the lateral controller being operably associated with the lateral control architecture.

17. The method of claim 16, further comprising:

20

resetting a lateral speed hold (909) with a lateral control hatch (907) as the lateral controller is moved out of a detent position, the lateral control hatch (907) being in data communication with the lateral control architecture.

18. The method of claim 17, wherein controlling the longitudinal direction of motion with the longitudinal control architecture comprises:

25

communicating longitudinal motion data through a longitudinal forward speed control loop (605);

communicating longitudinal motion data through a longitudinal pitch angle control loop (607); and

30

communicating longitudinal motion data through a longitudinal pitch rate control loop (609).

19. The method of claim 11, the longitudinal control architecture further comprising:
controlling the longitudinal direction of motion with a longitudinal controller
manipulated by a pilot controlling the aircraft (201), the longitudinal controller being
operably associated with the longitudinal control architecture.

5

20. The method of claim 19, further comprising:
resetting a longitudinal speed hold (911) with a longitudinal control hatch (905) as
the longitudinal controller is moved out of a detent position, the longitudinal control
hatch (905) being in data communication with the longitudinal control architecture.

10

FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Technical Field

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.

Description of the Prior Art

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.

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.

An example velocity command system is described in US 5553812, in which an aircraft flight path referenced velocities are determined with respect to an inertial frame of reference, the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that the aircraft maintains a fixed inertial referenced flight path regardless of the pointing direction of the aircraft. Velocity control with respect to an inertial frame of reference is accomplished by controlling the aircraft flight path

based on aircraft body referenced commanded lateral and longitudinal acceleration and based on aircraft body referenced lateral and longitudinal centrifugal acceleration. Operation in the velocity stabilization mode is provided in response to the manual activation of the velocity stabilization mode by the pilot, provided that the aircraft is already operating in the ground speed mode and the aircraft is not in a coordinated turn.

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.

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;

5 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

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

Description of the Preferred Embodiment

15 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. As a result of this auto-moding logic, 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.

5 The auto-moding logic 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
10 having to use cockpit switches to change modes.

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
15 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.

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
20 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.

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

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.



Letter accompanying subsequently filed items

Representative:

Mr John Lawrence
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham West Midlands B16 8QQ
United Kingdom

Phone: +44 121 4560000

Fax: +44 121 4561368

E-mail: bham@barkerbrettell.co.uk

80298 Munich

Germany

Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818

NL-2280 HV Rijswijk

Netherlands

Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin

Germany

Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number

11862189.5

Applicant's or representative's reference

JL69579P.EPA

	Description of document	Original file name	Assigned file name
1	Letter relating to the search and examination procedure	LTR_EPO_260615.pdf	EPLETT-1.pdf
2	Amended description with annotations	DECR_TRK_260615.pdf	DESC-HWA-1.pdf
3	Amended description (clean copy)	DECR_CLN_260615.pdf	DESC-1.pdf
4	Amended claims with annotations	CLMS_TRK_260615.pdf	CLMS-HWA-1.pdf
5	Amended claims (clean copy)	CLMS_CLN_260615.pdf	CLMS-1.pdf

Signatures

Place:

Derbyshire, UK

Date:

26 June 2015

Signed by:

Mark Thurston 27885

Representative name:

Dr Mark R Thurston

Capacity:

(Representative)

JL69579P.EPA



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Please reply to Birmingham Office
Contact: Dr Mark R. Thurston
Email: mark.thurston@barkerbrettell.co.uk

European Patent Office
D-80298 Munchen
Germany

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Your ref:

Our ref:

JL69579P.EPA/MRT

26 June 2015

Dear Sirs

**European Patent Application No. 11862189.5
In the name of Bell Helicopter Textron Inc.**

This is a response to the Communication issued pursuant to Article 94(3) EPC dated 17 February 2015.

We enclose an amended set of Claims 1 to 20 on replacement pages 14 to 19. Please substitute the enclosed claims for those currently on file. For the Examiner's convenience, we further enclose a reference copy of the claims, showing the amendments as tracked changes.

We have amended the last clause of Claim 1 to remove the reference to controlling "...a yaw movement of the aircraft" and have instead specified that the control system maintains "...a constant vector heading across a ground surface while the aircraft flies with a crab angle greater than zero". This amendment is supported throughout the specification as originally filed and in particular, by the description on page 9, line 4 through page 11, line 6.

We have also made a corresponding amendment to independent method Claim 11 and have corrected typographical errors in dependent Claims 7, 10, 15 & 16.

Thus, we assert that the amendments have basis and do not extend beyond the subject matter of the application in accordance with the requirements of Article 123(2) EPC.

For ease of reference, the following section numbers correspond to those of the Examiner's report.

§§2.1 & 2.2

As indicated above, we have amended both Claims 1 and 11 to specify that the "control system utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading across a ground surface while the aircraft flies with a crab angle greater than zero".

The Examiner acknowledges that the description clearly supports such an arrangement and consequently we submit that the objection under Article 84 EPC is now overcome.

§3.1

It is quite evident that the subject matter of amended Claim 1 is both novel and inventive over the cited prior art Document D1.

As amended, Claim 1 now requires that the control system maintain a constant vector heading across a ground surface **while the aircraft flies with a crab angle greater than zero**.

By contrast, Document D1 does not teach or suggest any embodiment that maintains a directional heading while the crab angle of the aircraft is above zero. In fact, D1 is actually completely silent with regards to mentioning the crab angle at all. Therefore, D1 does not anticipate, nor render obvious, the subject matter of amended Claim 1 and consequently this claim satisfies the requirements of Articles 54 & 56 EPC.

The same argument applies mutatis mutandis to the subject matter of amended independent method Claim 11, and therefore this claim also meets the requirements of the EPC as to novelty and inventive step over the prior art.

§3.2

The dependent Claims 2-10 and 12-20 each meet the requirements of Articles 54 & 56 EPC, not least, by virtue of their respective dependencies from amended Claims 1 and 11.

§5.1

As provided for in the Guidelines for Examination F-IV 2.3, we have maintained Claim 1 in one-part form to avoid a confusing presentation of claim. The Applicant believes that the use of the two-part form would be unsuitable in this case, as the re-arrangement of the features would likely give a distorted or misleading view of the claimed invention and/or prior art.

§5.2

We have inserted reference signs throughout the amended set of claims to satisfy the requirements of Rule 43(7) EPC.

§5.3

We have acknowledged document D1 in an amended description on page 1 to thereby meet the requirements of Rule 42(1)(b) EPC.

§5.6

We have deleted the referenced text in the description as requested by the Examiner and enclose amended description pages 3, 4 & 13 for substitution on file.

No subject-matter is abandoned by the present amendments and the Applicant reserves the right to reintroduce any subject-matter and/or file divisional application(s).

It is submitted that the application is now in condition for allowance. Favourable reconsideration of the application is requested. In the unlikely event that the Examiner is minded to issue as his next action a decision to refuse the application, we hereby request a telephone discussion and/or an informal interview with the Examiner. If the Examiner is minded to refuse the application, we request Oral Proceedings conditional upon that otherwise being the Examiner's intention. This request is made only as a precaution as we expect to make progress on the application via the usual written and telephone channels of communication.

Yours faithfully

SIGNED ELECTRONICALLY

Dr Mark R. Thurston – Professional Representative
for and on behalf of Barker Brettell LLP

enc.

The examination is being carried out on the **following application documents**

Main request

Description, Pages

1-13 as published

Claims, Numbers

1-20 filed in electronic form on 04-08-2014

Drawings, Sheets

1/9-9/9 as published

Auxiliary request

Description, Pages

1-13 as published

Claims, Numbers

1-15 filed in electronic form on 15-10-2014

Drawings, Sheets

1/9-9/9 as published

1 Prior Art

The following document is referred to in this communication:

D1 US 5 553 812 A (GOLD PHILLIP J [US] ET AL) 10 September 1996
(1996-09-10)

2 Objections under Article 84 EPC

- 2.1 The present independent claims 1 and 11 of the main request do not meet the requirements of Article 84 EPC because the subject-matter of claims 1 and 11 is not supported by the description.

The last three lines of claim 1 read as follows:

wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

However, it is clear from the description that the longitudinal controller and the lateral controller maintain the flight vector over ground constant while the airplane flies with a crab angle > 0 . Control of the "yawing turns" is provided by the directional controller of the helicopter, for example by the pedals in one embodiment of a helicopter (page 4, lines 1 - 7 and page 12, lines 15 - 23).

- 2.2 The same applies mutatis mutandis to the independent claim 11.

3 **Objections under Article 52(1) and 54(1,2) EPC (Novelty)**

- 3.1 The independent claims 1 and 11 of the main request of the present application do not meet the requirements of Article 52(1) EPC because the subject-matter of claims 1 and 11 is not new in the sense of Article 54(1) and (2) EPC.

Document D1 shows the following features:

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 a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface (col. 1, line 1 - col 2, line 22; col. 2, line 65 - col. 3, line 60; col. 4, lines 16 - 30; col. 5 lines 48 - 57; col. 6, lines 35 - 67).

It is noted that the model is an implicit feature. It is further noted that the "initialization command logic" is regarded as to be the "mixing device" (45) disclosed in the passages mentioned above and in figures 3 and 4.

Therefore, the subject-matter of claims 1 and 11 is not new (Article 54 EPC).

3.2 The remaining dependent claims 2 - 10 and 12 - 20 do not appear to contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the EPC with respect to novelty or inventive step, in view of the prior art at hand.

4 The objections under points 2 and 3.1 also apply to the independent claims 1 and 8 of the auxiliary request filed on 15.10.2014. This is due to the fact that the subject-matter of the independent claims 1 and 11 of the main request remain unchanged.

5 **Remarks**

It is not at present apparent which part of the application could serve as a basis for a new, allowable claim. Should the applicants nevertheless regard some particular matter as patentable, an independent claim should be filed taking account of Rule 43(1) EPC. The applicants should also indicate in the letter of reply the difference between the subject-matter of the new claim and the state of the art, and the significance thereof. In addition, they should be aware of the objections and formalities as follows:

- 5.1 Independent claims should be drafted in the two-part form. If in the applicant's view the two-part form is not suitable he should give reasons for that in his answer. In addition the applicant should clearly describe which features of the subject-matter of the new claim are already known from document **D1** (see Guidelines, C-III, 2.3b).
- 5.2 The features of the claims should be provided with reference signs placed in parentheses to increase the intelligibility of the claims (Rule 43(7) EPC). For independent claims this applies to both the preamble and characterising portion (see the Guidelines, C-III, 4.11).
- 5.3 To meet the requirements of Rule 42(1) b) EPC, the document **D1** should be identified in the description and the relevant background art disclosed therein should be briefly discussed.
- 5.4 When filing amended claims the applicant should at the same time bring the description into conformity with the amended claims. Care should be taken during revision, especially in the introductory portion and any statements of problem or advantage should be stated.
- 5.5 In order to facilitate the examination of the conformity of the amended application with the requirements of article 123(2) EPC, the applicant is requested to clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (Rule 137(4) EPC).
- 5.6 Lines 11 - 15 on page 3 and the last paragraph of the description should be deleted since they contain irrelevant matter (Rule 48(1) (c), EPC). The same applies to lines 22 - 25 on page 4. In the description it is mentioned that "*directional inputs turn aircraft 201 in a complete 360 degree yaw movement, stopping every 90 degrees, and without changing the speed and flight heading of aircraft 201*" (page 4, lines 20 - 22). However, this is only possible for rotary aircrafts. An aircraft which uses fixed wings to generate lift can not make such a movement. Therefore, the control system according to the invention is not adaptable with control systems of different types of aircraft (Article 83 EPC).



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME-UNI

Formalities Officer
Name: Novoa, Carlos
Tel: +49 89 2399 - 2718
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Pöllmann, H
Tel: +49 89 2399 - 6017

Application No. 11 862 189.5 - 1802	Ref. JL69579P.EPP	Date 17.02.2015
Applicant Bell Helicopter Textron Inc.		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Pöllmann, H
Primary Examiner
For the Examining Division

Enclosure(s): 4 page/s reasons (Form 2906)

Questions about this communication ?

Contact Customer Services at www.epo.org/contact



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME UNI

Date

23.12.14

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681
Applicant/Proprietor Bell Helicopter Textron Inc.	

Communication

The European search report (under R. 61 or R. 63 EPC) or the supplementary european search report (Art. 153(7) EPC) is enclosed. An official communication under Rule 71(1) or Rule 71(3) EPC will be dispatched in due course (R. 62 EPC).

Copies of documents cited in the European search report are attached.

☒ 0 additional set(s) of copies of such documents is (are) enclosed as well.

The following have been approved:

☒ Abstract ☒ Title

☐ The Abstract was modified and the definitive text is attached to this communication.

The following figure(s) will be published together with the abstract:

Refund of search fee

If applicable under Article 9 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.



SUPPLEMENTARY EUROPEAN SEARCH REPORT

Application Number
EP 11 86 2189

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 553 812 A (GOLD PHILLIP J [US] ET AL) 10 September 1996 (1996-09-10) * the whole document *	1-20	INV. G05D1/08 B64C19/00
A	US 5 553 817 A (GOLD PHILLIP J [US] ET AL) 10 September 1996 (1996-09-10) * the whole document *	1-20	
A	US 2003/106958 A1 (GOLD PHILLIP JEREMY [US] ET AL) 12 June 2003 (2003-06-12) * the whole document *	1-20	
The supplementary search report has been based on the last set of claims valid and available at the start of the search.			TECHNICAL FIELDS SEARCHED (IPC)
			G05D
Place of search		Date of completion of the search	Examiner
Munich		15 December 2014	Pöllmann, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

1

EPO FORM 1503 03.82 (P04C04)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 11 86 2189

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15-12-2014

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5553812	A	10-09-1996	AU 2544995 A	04-01-1996
			CA 2191861 A1	14-12-1995
			DE 69503631 D1	27-08-1998
			DE 69503631 T2	26-11-1998
			EP 0763222 A1	19-03-1997
			ES 2120206 T3	16-10-1998
			IL 113699 A	29-02-2000
			JP H10501198 A	03-02-1998
			KR 100369690 B1	09-05-2003
			US 5553812 A	10-09-1996
			WO 9534029 A1	14-12-1995

US 5553817	A	10-09-1996	AU 681279 B2	21-08-1997
			AU 2246895 A	29-11-1995
			CA 2189455 A1	09-11-1995
			DE 69504497 D1	08-10-1998
			DE 69504497 T2	28-01-1999
			EP 0759196 A1	26-02-1997
			ES 2121370 T3	16-11-1998
			IL 113318 A	30-10-1998
			JP H09512762 A	22-12-1997
			US 5553817 A	10-09-1996
			WO 9530181 A1	09-11-1995

US 2003106958	A1	12-06-2003	US 2003106958 A1	12-06-2003
			WO 03050631 A2	19-06-2003

Questions about this communication ?

Contact Customer Services at www.epo.org/contact



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham B16 8QQ
ROYAUME UNI

Date

22-12-2014

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681
Applicant/Proprietor Bell Helicopter Textron Inc.	

BRIEF COMMUNICATION

- Subject: ☒ Your letter of 15.10.2014
☐ Our telephone conversation of
☒ Communication of 05.09.2014 (EPO form 1226CC)
☐
 Enclosure(s): ☐ Letter from the proprietor of the patent of
☐ Copy (copies)
☒ Communication:

We refer to your letter dated 15.10.2014 and inform you as follows : due to technical problems, the applicant's request to waive his right to the communication under Rules 161(2) and 162 EPC was not properly encoded.
 Therefore EPO Form 1226CC dated 05.09.2014 is null and void.
 The communication pursuant to Art. 94(3) EPC will be despatched in due time after the issuance of the European Search Report.

We would like to apologise for any inconvenience caused.

Please take note.

Receiving Section



☐ **Registered letter**

EPO Form 2911 12.07 (17/12/14)

Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	3062133	
Application number	EP11862189.5	
Date of receipt	15 October 2014	
Receiving Office	European Patent Office, The Hague	
Your reference	JL69579P.EPP	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (1 p.) CLMS-1.pdfCLMS_Auxiliary_Clean_1 51014.pdf (6 p.)	ep-sfd-request.xml EPLETT-1.pdf\LTR_EPO_R162.pdf (2 p.) CLMS-HWA-1.pdfCLMS_Auxiliary_Tr acked_151014.pdf (6 p.)
Submitted by	CN=Neil Kilpatrick 41488	
Method of submission	Online	
Date and time receipt generated	15 October 2014, 15:51 (CEST)	
Message Digest	4E:62:DC:4A:96:8C:95:CE:35:8B:FD:4F:1A:69:32:ED:E4:BC:24:B3	

Correction by the EPO of errors in debit instructions filed by eOLF

Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

Claims

1. An aircraft, comprising:

a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

5 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:

10 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;

15 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;

20 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

25 wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

2. The aircraft of claim 1, the aircraft further comprising:

a directional control architecture, the aircraft further comprising:

a directional controller, the directional controller being manipulated by a pilot controlling the aircraft, the directional controller being in data communication with the control system, and optionally or preferably,

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.

3. The aircraft of claim 2, the directional control architecture comprising:

a directional heading control loop;

a directional turn coordination control loop; and

a directional yaw rate control loop.

4. The aircraft 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, and optionally or preferably wherein the aircraft further comprises:

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.

5. The aircraft of claim 4, 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.

6. The aircraft 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.

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7. The aircraft of claim 6, 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, and optionally or preferably wherein the aircraft further comprises:
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 latch resets a longitudinal speed hold.

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8. A method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising:

sensing a directional movement of the aircraft with a sensor carried by the aircraft, the directional movement having:

20

- a longitudinal direction of motion; and
- a lateral direction of motion;

controlling the directional movement of the aircraft with an actuator operably associated with the aircraft;

providing a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

25

- a model;
- a lateral control architecture in data communication with the model;
- a longitudinal control architecture in data communication with the model;

and

AUXILIARY REQUEST

- 17-

an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

5 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;

10 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;

15 wherein the control system receives sensed directional movement 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.

9. The method of claim 8, the method further comprising:

20 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft, the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system.

10. The method of claim 9, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

25 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.

11. The method of claim 9, further comprising:

activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position, the directional control latch being operably associated with the directional control architecture.

- 5 12. The method of claim 8 wherein controlling the lateral direction of motion with the or a lateral control architecture comprises:

communicating lateral motion data through a lateral sideward groundspeed control loop;

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

10 communicating lateral motion data through a lateral roll rate control loop.

13. The method of claim 8, further comprising:

controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft, the lateral controller being operably associated with the or a lateral control architecture.

15

14. The method of claim 13, further comprising:

resetting a lateral speed hold with a lateral control hatch as the lateral controller is moved out of a detent position, the lateral control hatch being in data communication with the lateral control architecture, and optionally or preferably wherein controlling the longitudinal direction of motion with the or a longitudinal control architecture comprises:

20

communicating longitudinal motion data through a longitudinal forward speed control loop;

communicating longitudinal motion data through a longitudinal pitch angle control loop; and

25

communicating longitudinal motion data through a longitudinal pitch rate control loop.

15. The method of claim 8, the longitudinal control architecture further comprising:

AUXILIARY REQUEST

- 19-

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture, and optionally or preferably further comprising:

- 5 resetting a longitudinal speed hold with a longitudinal control hatch as the longitudinal controller is moved out of a detent position, the longitudinal control hatch being in data communication with the longitudinal control architecture.

10

Claims

1. An aircraft, comprising:

a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

5 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:

10 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;

15 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;

20 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

25 wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

2. The aircraft of claim 1, the aircraft further comprising:

a directional control architecture, the aircraft further comprising:

_____a directional controller, the directional controller being manipulated by a pilot controlling the aircraft, the directional controller being in data communication with the control system, and optionally or preferably, -

~~4. The aircraft of claim 2, 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.

3. The aircraft of claim 2, the directional control architecture comprising:

a directional heading control loop;
a directional turn coordination control loop; and
a directional yaw rate control loop.

~~5~~4. The aircraft 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, and optionally or preferably, -

~~6. The aircraft of claim 5, wherein the aircraft further comprises:~~

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~~5. The aircraft of claim ~~6~~4, 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 latch resets a lateral speed hold.

5 | 86. The aircraft 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.

10 | 97. The aircraft of claim 86, 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
15 | loop, and optionally or preferably wherein the aircraft.

~~10. The aircraft 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
20 | longitudinal control latch resets a longitudinal speed hold.

| 448. A method to control flat yawing turns of an aircraft while maintaining a constant
vector heading across a ground surface, the method comprising:
sensing a directional movement of the aircraft with a sensor carried by the
25 | aircraft, the directional movement having:
a longitudinal direction of motion; and
a lateral direction of motion;
controlling the directional movement of the aircraft with an actuator operably
associated with the aircraft;

providing a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

a model;

a lateral control architecture in data communication with the model;

5 a longitudinal control architecture in data communication with the model;

and

an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

10 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;

15 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;

20 wherein the control system receives sensed directional movement 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.

| 429. The method of claim ~~448~~, the method further comprising:

25 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft, the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system.

| ~~4310~~. The method of claim ~~429~~, wherein the commanding of the flat yawing turns with
30 the directional control architecture 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.

5 | ~~44~~11. The method of claim ~~42~~9, further comprising:

activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position, the directional control latch being operably associated with the directional control architecture.

10 | ~~45~~12. The method of claim ~~44~~8 wherein controlling the lateral direction of motion with the or a lateral control architecture comprises:

communicating lateral motion data through a lateral sideward groundspeed control loop;

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

15 | communicating lateral motion data through a lateral roll rate control loop.

| ~~46~~13. The method of claim ~~44~~8, further comprising:

controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft, the lateral controller being operably associated with the or a lateral control architecture.

20

| ~~47~~14. The method of claim ~~46~~13, further comprising:

resetting a lateral speed hold with a lateral control hatch as the lateral controller is moved out of a detent position, the lateral control hatch being in data communication with the lateral control architecture, and optionally or preferably;

25

~~18. The method of claim 17, wherein controlling the longitudinal direction of motion with the or a longitudinal control architecture comprises:~~

communicating longitudinal motion data through a longitudinal forward speed control loop;

30

communicating longitudinal motion data through a longitudinal pitch angle control loop; and

communicating longitudinal motion data through a longitudinal pitch rate control loop.

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| ~~19~~15. The method of claim ~~14~~8, the longitudinal control architecture further comprising:
controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture, and optionally or preferably

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| ~~20.~~ The method 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 longitudinal control hatch being in data communication with the longitudinal control architecture.

15



Letter accompanying subsequently filed items

Representative:

Mr John Lawrence
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham West Midlands B16 8QQ
United Kingdom

Phone: +44 121 4560000

Fax: +44 121 4561368

E-mail: bham@barkerbrettell.co.uk

80298 Munich

Germany

Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818

NL-2280 HV Rijswijk

Netherlands

Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin

Germany

Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number

11862189.5

Applicant's or representative's reference

JL69579P.EPP

	Description of document	Original file name	Assigned file name
1	Letter relating to the search and examination procedure	LTR_EPO_R162.pdf	EPLETT-1.pdf
2	Amended claims (clean copy)	CLMS_Auxiliary_Clean_151014.pdf	CLMS-1.pdf
3	Amended claims with annotations	CLMS_Auxiliary_Tracked_151014.pdf	CLMS-HWA-1.pdf

Signatures

Place:

Birmingham, UK

Date:

15 October 2014

Signed by:

Neil Kilpatrick 41488

Capacity:

(Representative)



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PATENTS TRADE MARKS COPYRIGHT DESIGNS

Please reply to Birmingham Office

Contact: Mr John Lawrence

Email: john.lawrence@barkerbrettell.co.uk

European Patent Office
D-80298 Munchen
Germany

SENT ELECTRONICALLY

Your ref:

11862189.5 - 1802

Our ref:

JL69579P.EPP/NGK

15 October 2014

Dear Sirs

**European Patent Application No. 11862189.5
In the name of Bell Helicopter Textron Inc.**

This is a response to the communication pursuant to Rule 161(2) and 162 EPC dated 5 September 2014.

Main Request

The currently pending claims are believed to be those submitted on filing, namely claims 1 to 13. We previously (4 August 2014) elected independent claims 1 and 2 in response to a communication under Rule 62a(1) EPC dated 3 June 2014 and in accordance with Guidelines for Examination B VIII 4.2.

Furthermore, we filed a statement of the subject matter to be searched in the form of an amended claim set in response to the communication under Rule 63 EPC dated 3 June 2014. This statement corresponded to the as-filed PCT claims 1 to 20 in accordance with Guidelines for Examination B VIII 3.2.2.

We note that the above referenced 5 September 2014 communication invites us to pay claim fees under Rule 162 EPC for claims 1 to 20 submitted (presumably) on 4 August 2014. However, as acknowledged by the communication also dated 5 September 2014 (EPO form reference 1063) and in accordance with the Guidelines, the claims 1 to 20 submitted on 4 August 2014 are not considered as amended claims (Rule 137(1) EPC) but merely as an indication of the subject-matter to be searched. We further note that the right of the applicant to amend the claims under Rule 161(2) EPC was waived on filing. Accordingly, it is believed that the communication pursuant to Rule 161(2) and 162 EPC was issued in error and that no claim fees are due. Search of the application should therefore be based on claims 1 and 2 elected on 4 August 2014 and the subject matter of claims 1 to 20 (the as-filed PCT claims) filed on 4 August 2014.

100 HAGLEY ROAD EDGBASTON BIRMINGHAM B16 8QQ ENGLAND TEL: + 44 (0)121 456 0000 FAX: +44 (0)121 456 1368

Email: bham@barkerbrettell.co.uk URL: www.barkerbrettell.co.uk

London Southampton Cambridge Malvern Science Park

Barker Brettell LLP is a limited liability partnership registered in England and Wales, registered number OC334393

Registered address: 100 Hagley Road Edgbaston Birmingham B16 8QQ England, where a list of members may be inspected

Regulated by the Intellectual Property Regulation Board

A reference to a partner means a member of Barker Brettell LLP or an employee or consultant of Barker Brettell LLP with equivalent standing and qualifications

Auxiliary Request

In the event that our understanding outlined in the main request is incorrect, we hereby submit an amended claim set of 15 claims based on the PCT claims as filed. The amended claims are a consolidated version of the as-filed PCT claims. Support for the amended claims is shown in the attached reference copy. One minor further change is to provide antecedent basis in claim 2 for the directional control architecture referred to in claim 3 (and former claim 4, now in claim 2).

We believe that the above represents a comprehensive and complete response to all of the examiner's objections. Any amendment should not be construed as abandonment of subject matter. In an abundance of caution, we request oral proceedings before any refusal of the application.

For the avoidance of doubt, if the Rule 161(2) EPC invitation was issued in error, we wish the subject matter of the PCT claims to be searched and it is our intent to formally maintain claims based on the scope of the PCT claims (and numbering less than 15) during prosecution in response to the extended European search report. Conversely, if the communication under Rule 161(2) EPC was not issued in error, we wish the subject matter of the attached claims to be searched and to form the basis of prosecution.

Yours faithfully

<signed electronically>

John Lawrence – Professional Representative
for and on behalf of Barker Brettell LLP





Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham
B16 8QQ
ROYAUME UNI

Questions about this communication ?

Contact Customer Services at www.epo.org/contact

Formalities officer: Ms Amélie Didier

Please specify the name of the formalities officer when
contacting Customer Services by contact form or phone.

Date

05-09-2014

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

☐ **Non-acceptance of amendments pursuant to Rules 137 (1) EPC**

The amendments filed on with respect to the above-mentioned European patent application cannot be accepted since they were filed prior to your receipt of the European search report (Rule 137 (1) EPC).

If it is intended to maintain the amendments, a statement to that effect should be filed after receipt of the European search report. In the case of amendments to the claims, these will be published together with the application in accordance with Rule 68 (4) EPC if the statement is received before termination of the technical preparations for publication.

☐ **Non-acceptance of amendments pursuant to Rule 161 (2) EPC**

The amendments filed on with respect to the above-mentioned Euro-PCT application cannot be accepted since they were filed after expiry of the period laid down in Rule 161 (2) EPC (EPO Form 1226CC dated) and therefore cannot form the basis for the supplementary European search.

If it is intended to maintain the amendments, a statement to that effect should be filed after receipt of the supplementary European search report as foreseen under Rules 70a (2) and 137 (2) EPC.

☒ **Acknowledgment of claims filed in reply to an invitation pursuant to Rule 62a (1) / 63 (1) EPC**

Reworded claims were submitted on 04.08.2014 with the letter of reply to the invitation pursuant to Rule 62a (1) / 63 (1) EPC.

Note that these claims were received prior to your receipt of the (supplementary) European search report and are not considered as amended claims (Rule 137 (1) EPC), but merely as an indication of the subject-matter to be searched in respect of the claims as originally filed, or serving as the basis for the supplementary European search (Rule 161 (2) EPC).

If the applicant wishes to introduce these claims formally in the proceedings, he should file a statement to that effect with the response to the extended European search report (Rules 70a (1) (2) EPC).

The applicant's attention is drawn to the fact that any amendments filed shall be identified and the basis for them in the application as filed needs to be indicated. Failure to meet either requirement may lead to a communication from the Examining Division requesting to correct this deficiency (Rule 137 (4) EPC).

Receiving Section



Questions about this communication ?

Contact Customer Services at www.epo.org/contact



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham
B16 8QQ
ROYAUME UNI

Date

05.09.14

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

Communication pursuant to Rules 161(2) and 162 EPC

1. Amendment of the application (R. 161(2) EPC)

The above-mentioned international (Euro-PCT) application has entered the European phase.

Under Articles 28, 41 PCT and Rules 52, 78 PCT the application may be amended before a designated or elected Office.

In accordance with Rule 161(2) EPC, you may amend your application once within a **non-extendable period of six months** after notification of the present communication.

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

The claims applicable on expiry of this period, i.e. those filed on entry into the European phase or in response to the present communication, will form the basis for the calculation of any claims fee to be paid (see page 2).

2 Claims fees under Rule 162 EPC

If the application documents on which the European grant procedure is to be based comprise more than fifteen claims, a claims fee shall be payable for the sixteenth and each subsequent claim within the period provided for in Rule 159(1) EPC.

- ☐ Based on the application documents currently on file, all necessary claims fees have already been paid (or the documents do not comprise more than 15 claims).
- ☐ All necessary fees will be debited automatically according to the automatic debit order.
- ☒ The claims fees due for the claims 16 to 20 were not paid within the above-mentioned period.

Any outstanding claims fee, either based on the current set of claims or on any amended claims to be filed pursuant to Rule 161 EPC (see page 1), may still be validly paid within a **non-extendable period of six months** after notification of this communication (R. 162(2) EPC).

If a payment is made for only some of the claims, you must indicate for which claims it is intended. If a claims fee is not paid in due time, the claim concerned is deemed to be abandoned (R. 162(4) EPC).

If claims fees have already been paid, but on expiry of the above-mentioned period there is a new set of claims containing fewer fee-incurring claims than before, the claims fees in excess of those due under Rule 162(2), second sentence EPC will be refunded (R. 162(3) EPC).

You are reminded that the supplementary search carried out according to Article 153(7) EPC will relate only to the last set of claims applicable on expiry of the above period AND will be confined to those fee-incurring claims for which fees have been paid in due time.

The claims fee is currently

EUR 235 for the 16th and each subsequent claim up to the limit of 50
EUR 580 for the 51st and each subsequent claim

Note to users of the automatic debiting procedure

Unless the EPO receives prior instructions to the contrary, the fees for all claims incurring fees will be debited on the last day of the period for payment. For further details see the Arrangements for the automatic debiting procedure, Annex A.1 to the ADA, Point 6.1(d), Supplementary publication 4 - OJ EPO 2014.

Important information concerning fee amounts

Following any amendment to the Rules relating to Fees, the amount(s) mentioned in this communication may be different from the amount(s) **actually due on the date of payment**. The latest version of the Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, is also available on the EPO website (www.epo.org) and can be found under www.epo.org/schedule-of-fees, which allows the viewing, downloading and searching for individual fee amounts, both current and previous.

Please note that procedural fees are usually adjusted every two years, on even years, with effect from 1 April.

Payments by cheque delivered or sent direct to the EPO are no longer accepted as from 1 April 2008 (see OJ EPO 2007, 626).

Receiving Section



Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	2923818	
Application number	EP11862189.5	
Date of receipt	04 August 2014	
Receiving Office	European Patent Office, The Hague	
Your reference	JL69579P.EPP	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (1 p.) CLMS-1.pdf\CLMS_Clean_040814.pdf (6 p.)	ep-sfd-request.xml CLMS-HWA-1.pdf\CLMS_Tracked_04 0814.pdf (7 p.) EPLETT-1.pdf\LTR_EPO_040814.pdf (1 p.)
Submitted by	CN=John Lawrence 16522	
Method of submission	Online	
Date and time receipt generated	04 August 2014, 17:31 (CEST)	
Message Digest	44:9C:37:84:47:2D:F5:8F:2A:54:E3:4B:D6:5F:66:48:D7:18:97:C5	

Correction by the EPO of errors in debit instructions filed by eOLF

Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

Claims

1. An aircraft, comprising:

a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

5 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:

10 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;

15 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;

20 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

25 wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

| 211. A method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising:

sensing a directional movement of the aircraft with a sensor carried by the aircraft, the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

5 controlling the directional movement of the aircraft with an actuator operably associated with the aircraft;

providing a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

a model;

10 a lateral control architecture in data communication with the model;

a longitudinal control architecture in data communication with the model;

and

15 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;

20 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;

25 wherein the control system receives sensed directional movement 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.

3. 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.~~

4. ~~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.~~

~~52. The aircraft of claim 1, or the control system of claim 3, the aircraft or control system further comprising:~~

~~a directional controller, the directional controller being manipulated by a pilot controlling the aircraft, the directional controller being in data communication with the control system;~~

~~12. or the method of claim 112 or of claim 4, the methods further comprising:~~

~~commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft, the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system.~~

~~63. The aircraft or control system of claim 52, the directional control architecture comprising:~~

~~a directional heading control loop;~~

~~a directional turn coordination control loop; and~~

a directional yaw rate control loop;

~~13. or either of~~ The methods of claim ~~5~~12, wherein the commanding of the flat yawing turns with the directional control architecture 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 aircraft or control system of claim 5~~2, 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;

~~14. either of~~ The methods of claim ~~5~~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, the directional control latch being operably associated with the directional control architecture.

~~15. The aircraft of claim 1 or control system of claim 5~~5, the lateral control architecture comprising:

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

~~15. The method of claim 2-11 or of claim 4~~4, wherein controlling the lateral direction of motion with the or a lateral control architecture comprises:

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.

96. ~~The aircraft or control system of claim 85,~~ 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.

~~;~~ or

16. ~~the~~ The method of claim 11 ~~2 or of claim 4,~~ further comprising:
controlling the lateral direction of motion with a lateral controller manipulated by a
pilot controlling the aircraft, the lateral controller being operably associated with the or a
lateral control architecture.

107. ~~The aircraft or control system of claim 96,~~ 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.

17. ~~either of the methods of claim 916,~~ further comprising:
resetting a lateral speed hold with a lateral control hatch as the lateral controller
is moved out of a detent position, the lateral control hatch being in data communication
with the lateral control architecture.

118. The aircraft of claim 1 ~~or the control system of claim 3,~~ the longitudinal control
architecture comprising:
a longitudinal forward speed control loop;
a longitudinal pitch angle control loop; and
a longitudinal pitch rate control loop.

~~;~~ or

18. ~~either of~~ The methods of claim ~~10~~17, wherein controlling the longitudinal direction of motion with the or a longitudinal control architecture comprises:

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.

~~129. The aircraft or the control system of claim 118,~~ 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.

~~;~~ ~~or~~

19. ~~either of~~ The methods of claim 11, the longitudinal control architecture further comprising:

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture.

~~1310. The aircraft or the control system of claim 129,~~ 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 latch resets a longitudinal speed hold.

~~;~~ ~~or~~

20. ~~either of the~~ The methods of claim 12~~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 longitudinal control hatch being in data communication with the longitudinal control architecture.

Claims

1. An aircraft, comprising:

a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

5 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:

10 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;

15 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;

20 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

25 wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

2. The aircraft of claim 1, the aircraft further comprising:
a directional controller, the directional controller being manipulated by a pilot
controlling the aircraft, the directional controller being in data communication with the
control system.

3. The aircraft of claim 2, the directional control architecture comprising:
a directional heading control loop;
a directional turn coordination control loop; and
a directional yaw rate control loop.

4. The aircraft of claim 2, 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 aircraft 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 aircraft 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 aircraft 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 latch resets a lateral speed hold.

8. The aircraft 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 aircraft 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 aircraft 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 latch resets a longitudinal speed hold.

11. A method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising:

sensing a directional movement of the aircraft with a sensor carried by the aircraft, the directional movement having:

a longitudinal direction of motion; and
a lateral direction of motion;

controlling the directional movement of the aircraft with an actuator operably associated with the aircraft;

providing a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

a model;

a lateral control architecture in data communication with the model;

a longitudinal control architecture in data communication with the model;

and

5 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;

10 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

15 selectively activating the lateral control architecture and the longitudinal control architecture with the initialization command logic;

wherein the control system receives sensed directional movement 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.

20 12. The method of claim 11, the method further comprising:

commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft, the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system.

25

13. The method of claim 12, wherein the commanding of the flat yawing turns with the directional control architecture comprises:

communicating data through a directional heading control loop;

30 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, the directional control latch being operably associated with the directional control architecture.

15. The method of claim 11 wherein controlling the lateral direction of motion with the or a lateral control architecture comprises:

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 the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft, the lateral controller being operably associated with the or a lateral control architecture.

17. The method 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, the lateral control hatch being in data communication with the lateral control architecture.

18. The method of claim 17, wherein controlling the longitudinal direction of motion with the or a longitudinal control architecture comprises:

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 method of claim 11, the longitudinal control architecture further comprising:
controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture.

20. The method 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 longitudinal control hatch being in data communication with the longitudinal control architecture.



Letter accompanying subsequently filed items

Representative:

Mr John Lawrence
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham West Midlands B16 8QQ
United Kingdom

Phone: +44 121 4560000

Fax: +44 121 4561368

E-mail: bham@barkerbrettell.co.uk

80298 Munich

Germany

Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818

NL-2280 HV Rijswijk

Netherlands

Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin

Germany

Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number

11862189.5

Applicant's or representative's reference

JL69579P.EPP

	Description of document	Original file name	Assigned file name
1	Amended claims with annotations	CLMS_Tracked_040814.pdf	CLMS-HWA-1.pdf
2	Amended claims (clean copy)	CLMS_Clean_040814.pdf	CLMS-1.pdf
3	Letter relating to the search and examination procedure	LTR_EPO_040814.pdf	EPLETT-1.pdf

Signatures

Place:

Birmingham,UK

Date:

04 August 2014

Signed by:

John Lawrence 16522

Capacity:

(Representative)

JL69579P.EPP



BARKER BRETTCELL

PATENTS TRADE MARKS COPYRIGHT DESIGNS

Please reply to Birmingham Office

Contact: Mr John Lawrence

Email: john.lawrence@barkerbrettell.co.uk

European Patent Office
D-80298 Munchen
Germany

SENT ELECTRONICALLY

Your ref:

11862189.5 - 1802

Our ref:

JL69579P.EPP/NGK

4 August 2014

Dear Sirs

**European Patent Application No. 11862189.5
In the name of Bell Helicopter Textron Inc.**

In response to the invitation pursuant to Rule 62a(1) EPC dated 3 June 2014, we hereby confirm that the first claim in each category identified, namely claims 1 and 2 should form the basis of the search.

Additionally, in response to the accompanying invitation pursuant to Rule 63(1) EPC, we hereby provide an amended claim set to form the basis of a statement indicating the subject matter to be searched. The amended claim set substantially corresponds to the as-published PCT claims.

Given that the PCT claims are contained within the as-filed currently pending claims (see marked version of the claims), we submit that the Examiner can now conduct a search of the claim set.

In the unlikely event that the Examiner intends to refuse the present application, oral proceedings are requested as a precaution.

Yours faithfully

John Lawrence – Professional Representative
for and on behalf of Barker Brettell LLP

100 HAGLEY ROAD EDGBASTON BIRMINGHAM B16 8QQ ENGLAND TEL: + 44 (0)121 456 0000 FAX: +44 (0)121 456 1368

Email: bham@barkerbrettell.co.uk URL: www.barkerbrettell.co.uk

London Southampton Cambridge Malvern Science Park

Barker Brettell LLP is a limited liability partnership registered in England and Wales, registered number OC334393

Registered address: 100 Hagley Road Edgbaston Birmingham B16 8QQ England, where a list of members may be inspected

Regulated by the Intellectual Property Regulation Board

A reference to a partner means a member of Barker Brettell LLP or an employee or consultant of Barker Brettell LLP with equivalent standing and qualifications

Claims 5 - 13 are unclear to such an extent that a meaningful search appears not possible (Article 84 EPC).

Claim 5 refers to the aircraft of claim 1 or the control system of claim 3 or the method of claim 2 or the method of claim 4. First of all, the category of said claim 5 is unclear. Further, the dependencies are unclear since a claim can not depend on an apparatus claim and a method claim at the same time. The unclarity mentioned before leaves the skilled reader in doubt about the subject-matter of claim 5.

The same applies mutatis mutandis to the dependent claim 8.

The remaining dependent claims 6, 7 and 9 - 13 show a similar problem or depend on claims which are unclear.

Therefore, a meaningful search is not possible.



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham
B16 8QQ
ROYAUME-UNI

Formalities Officer
Name: Camps, Ester
Tel: +49 89 2399 - 2237
or call
+31 (0)70 340 45 00

Application No. 11 862 189.5 - 1802	Ref. JL69579P.EPP	Date 03.06.2014
Applicant Bell Helicopter Textron Inc.		

Invitation pursuant to Rule 62a(1) EPC and Rule 63(1) EPC

In the above-mentioned European patent application as filed, the search division has identified multiple independent claims in the same category. In accordance with Rule 62a(1) EPC, the applicant is invited to indicate the claims complying with Rule 43(2) EPC on the basis of which the search is to be carried out.

The following groups of independent claims in the same category have been identified:

Category Apparatus	Independent claims	1, 3
Category Method	Independent claims	2, 4

The EPO also considers that the above-mentioned European patent application fails to comply with the European Patent Convention to such an extent that it is impossible to carry out a meaningful search regarding the state of the art on the basis of all or some of the subject-matter claimed. In accordance with Rule 63(1) EPC, the applicant is invited to file a statement indicating the subject-matter to be searched.

Claims which the Search Division considers cannot be searched at all: 5-13

See Annex (EPO Form 2906) for the reasons.

You are invited to file the required indication and statement within a period of

two months

from the notification of this communication.

If the indication according to Rule 62a EPC is filed in due time, the subsequent search report will be issued with respect to the relevant claim / claims in the category concerned.

Failure to comply with this invitation in due time will result in the search report being drawn up on the basis of the first independent claim in each category (R. 62a(1) EPC). Should the applicant contest the objection under Rule 62a EPC, a final decision on the matter may be taken in the course of substantive examination proceedings before the Examining Division.

If the statement according to Rule 63(1) EPC indicating the subject-matter to be searched is submitted in due time and the statement is sufficient to overcome the deficiencies, the subsequent search report will be issued with respect to the relevant subject-matter.

Failure to comply with this invitation by either not replying in due time or not sufficiently overcoming the deficiency raised will result in either a reasoned declaration stating that it is impossible to carry out a meaningful search or a partial search report as far as is practicable (R. 63(2) EPC). Should the applicant contest the objection under Rule 63(1) EPC, a final decision on the matter may be taken in the course of substantive examination proceedings before the Examining Division (R. 63(3) EPC).

Re-establishment of rights (Art. 122 EPC)

An applicant who, in spite of all due care required by the circumstances having been taken, was unable to observe a time limit, shall have his rights re-established upon request, provided that the time limits and other requirements of Rule 136(1) and (2) EPC are met.



Search Examiner

Enclosure(s): reasons (Form 2906)

Application No.: 11862189.5

The search has started on 28.05.14 (see Notice from the European Patent Office dated 03/2013, OJ EPO 2013, 153).

Receiving Section



Lawrence, John
Barker Brettell LLP
100 Hagley Road
Edgbaston
Birmingham
B16 8QQ
ROYAUME UNI

**For any questions about
this communication:**

Tel.: +31 (0)70 340 45 00

Date

20.11.13

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 / 2673681 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

Communication of European publication number and information on the application of Article 67(3) EPC

The provisional protection under Article 67(1) and (2) EPC in the individual Contracting States becomes effective only when the conditions referred to in Article 67(3) EPC have been fulfilled (for further details, see information brochure of the European Patent Office "National Law relating to the EPC" and additional information in the Official Journal of the European Patent Office).

A request has been made for extension of the patent to: BA ME

See Official Journal 1-2/1994 for further information on provisional protection.

Pursuant to Article 153(3) EPC the publication under Article 21 PCT of an international application for which the European Patent Office is a designated or elected Office takes the place of the publication of a European patent application.

The bibliographic data of the above-mentioned Euro-PCT application will be published on 18.12.13 in Section I.1 of the European Patent Bulletin. The European publication number is 2673681.

In all future communications to the European Patent Office, please quote the application number plus Directorate number.

Receiving Section





CHRISTENSEN, Kevin, Thomas
3905 Branchwood Drive
Plano
TX 75093
ETATS-UNIS D'AMERIQUE

**For any questions about
this communication:**
Tel.: +31 (0)70 340 45 00

Date
05.11.13

Reference	Application No./Patent No. 11862189.5 - 1802 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

Notification of the data mentioned in Rule 19(3) EPC

In the above-identified patent application you are designated as inventor/co-inventor.
Pursuant to Rule 19(3) EPC the following data are notified herewith:

DATE OF FILING : 30.03.11

PRIORITY : //

TITLE : FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT
TURNS

DESIGNATED STATES : AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE
IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM
TR

Receiving Section





SHUE, Shyhyng, Jack
2809 Woodland Hills Drive
Grapevine
TX 76051
ETATS-UNIS D'AMERIQUE

**For any questions about
this communication:**
Tel.: +31 (0)70 340 45 00

Date
05.11.13

Reference	Application No./Patent No. 11862189.5 - 1802 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

Notification of the data mentioned in Rule 19(3) EPC

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TITLE : FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT
TURNS

DESIGNATED STATES : AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE
IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM
TR

Receiving Section





CAUDILL, Troy, Sheldon
6195 Oak Hollow Drive
Burleson
TX 76028
ETATS-UNIS D'AMERIQUE

**For any questions about
this communication:**
Tel.: +31 (0)70 340 45 00

Date
05.11.13

Reference	Application No./Patent No. 11862189.5 - 1802 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

Notification of the data mentioned in Rule 19(3) EPC

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Pursuant to Rule 19(3) EPC the following data are notified herewith:

DATE OF FILING : 30.03.11

PRIORITY : //

TITLE : FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT
TURNS

DESIGNATED STATES : AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE
IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM
TR

Receiving Section



PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

Applicant's or agent's file reference 0837RF-H793P	FOR FURTHER ACTION	See item 4 below
International application No. PCT/US2011/030498	International filing date (<i>day/month/year</i>) 30 March 2011 (30.03.2011)	Priority date (<i>day/month/year</i>)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant BELL HELICOPTER TEXTRON INC.		

1.	This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 bis.1(a).																								
2.	This REPORT consists of a total of 5 sheets, including this cover sheet.																								
In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.																									
3.	This report contains indications relating to the following items: <table style="width: 100%;"> <tr> <td style="width: 5%; text-align: center;">☒</td> <td style="width: 25%;">Box No. I</td> <td>Basis of the report</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. II</td> <td>Priority</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. III</td> <td>Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. IV</td> <td>Lack of unity of invention</td> </tr> <tr> <td style="text-align: center;">☒</td> <td>Box No. V</td> <td>Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VI</td> <td>Certain documents cited</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VII</td> <td>Certain defects in the international application</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VIII</td> <td>Certain observations on the international application</td> </tr> </table>	☒	Box No. I	Basis of the report	☐	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 Article 35(2) 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
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☐	Box No. VIII	Certain observations on the international application																							
4.	The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).																								

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 5px;">Date of issuance of this report 01 October 2013 (01.10.2013)</td> </tr> <tr> <td style="padding: 5px;"> Authorized officer Kihwan Moon </td> </tr> <tr> <td style="padding: 5px;">e-mail: pt01.pct@wipo.int</td> </tr> </table>	Date of issuance of this report 01 October 2013 (01.10.2013)	Authorized officer Kihwan Moon	e-mail: pt01.pct@wipo.int
Date of issuance of this report 01 October 2013 (01.10.2013)				
Authorized officer Kihwan Moon				
e-mail: pt01.pct@wipo.int				

Form PCT/IB/373 (January 2004)

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

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

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 43*bis*.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)

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2011/030498

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.

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY
(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

Applicant's or agent's file reference 0837RF-H793P	FOR FURTHER ACTION	See item 4 below
International application No. PCT/US2011/030498	International filing date (<i>day/month/year</i>) 30 March 2011 (30.03.2011)	Priority date (<i>day/month/year</i>)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant BELL HELICOPTER TEXTRON INC.		

1. This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 bis.1(a).

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.

3. This report contains indications relating to the following items:

- | | | |
|-------------------------------------|--------------|---|
| ☒ | Box No. I | Basis of the report |
| ☐ | 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 Article 35(2) 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 |

4. The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Date of issuance of this report 01 October 2013 (01.10.2013)
Facsimile No. +41 22 338 82 70	Authorized officer Kihwan Moon e-mail: pt01.pct@wipo.int

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

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

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
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- ☒ 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)

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2011/030498

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.

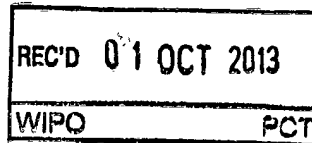
Claims 1-20 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.



European Patent Office
Postbus 5818
2280 HV RIJSWIJK
NETHERLANDS
Tel. +31 (0)70 340-2040
Fax +31 (0)70 340-3016



WIPO
The International Bureau
34, Chemin des Colombettes
CH-1211 GENEVA 20
SWITZERLAND



Formalities Officer
Name: Slater, Sharon
Tel.: +49 (0)89 2399-2565
or call:
+31 (0)70 340 45 00

EPO - DG 2

10. 10. 2013

Date
30-09-2013

Reference JL69579P.EPP	Application No./Patent No. 11862189.5 - 1802 PCT/US2011030498 / ISA US
Applicant/Proprietor Bell Helicopter Textron Inc.	

For the aforementioned international application, the following documents are not available in Patentscope. You are kindly requested to forward to the EPO in its capacity as designated / elected Office:

- ☐ a) the publication of the international search report (Art. 20 PCT).
- ☐ b) the International Preliminary Examination Report (Art. 36(3)(a) PCT, R. 73.2(a) PCT).
- ☐ c) the copy (copies) of the priority document(s)
.....
☐ according to PCT/RO/101 the applicant has complied with Rule 17.1(a), (b) or (b-bis) PCT.
- ☐ d) the International Preliminary Report on Patentability (Chapter I) (R. 44bis.2(a) PCT).
- ☐ e) the translation of the International Preliminary Report on Patentability (Chapter I) (R.44bis .3(c) PCT).
- ☒ f) **within the shortest possible delay, due to a request for early processing** (Art. 23(2) or 40(2) PCT):
 - ☒ the International Preliminary Report on Patentability (Chapter I) (R.44bis 2(b) PCT)
 - ☐ the translation of the International Preliminary Report on Patentability (Chapter I) (R.44bis.3(d) PCT)
 - ☐ the International Preliminary Examination Report or a copy of the written opinion established by the ISA (R. 73.2(b) PCT).
 - ☐ the documents of the international application according to Article 20 PCT prior to international publication (R. 47.4 PCT).
- ☐

Receiving Section

Answer of the International Bureau [IB]:

- ☐ The requested item(s) [a), b), c), d), e) and/or f)] is (are) not available to the IB.
Remarks:
- ☐ The requested item(s) [a), b), c), d), e) and/or f)] is (are) defective and cannot be communicated.
Remarks:
 - ☐ The Receiving Office/International Searching Authority/International Preliminary Examining Authority has been contacted.
- ☒ The requested item(s) is/are enclosed.
Remarks: IPRP I

The International Bureau

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

Applicant's or agent's file reference 0837RF-H793P	FOR FURTHER ACTION	See item 4 below
International application No. PCT/US2011/030498	International filing date (<i>day/month/year</i>) 30 March 2011 (30.03.2011)	Priority date (<i>day/month/year</i>)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant BELL HELICOPTER TEXTRON INC.		

1.	This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 bis.1(a).																								
2.	This REPORT consists of a total of 5 sheets, including this cover sheet.																								
In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.																									
3.	This report contains indications relating to the following items: <table style="width: 100%;"> <tr> <td style="width: 5%; text-align: center;">☒</td> <td style="width: 25%;">Box No. I</td> <td style="width: 70%;">Basis of the report</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. II</td> <td>Priority</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. III</td> <td>Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. IV</td> <td>Lack of unity of invention</td> </tr> <tr> <td style="text-align: center;">☒</td> <td>Box No. V</td> <td>Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VI</td> <td>Certain documents cited</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VII</td> <td>Certain defects in the international application</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VIII</td> <td>Certain observations on the international application</td> </tr> </table>	☒	Box No. I	Basis of the report	☐	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 Article 35(2) 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
☒	Box No. I	Basis of the report																							
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☐	Box No. VI	Certain documents cited																							
☐	Box No. VII	Certain defects in the international application																							
☐	Box No. VIII	Certain observations on the international application																							
4.	The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).																								

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	Date of issuance of this report 01 October 2013 (01.10.2013) Authorized officer Kihwan Moon e-mail: pt01.pct@wipo.int
--	---

Form PCT/IB/373 (January 2004)

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

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

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)

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2011/030498

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.

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

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

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 43*bis*.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)

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2011/030498

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.

Acknowledgement of receipt

We hereby acknowledge receipt of the form for entry into the European phase (EPO as designated or elected Office) as follows:

Submission number	2295246	
PCT application number	PCT/US2011/030498	
EP application number	11862189.5	
Date of receipt	11 September 2013	
Receiving Office	European Patent Office, The Hague	
Your reference	JL69579P.EPP	
Applicant		
Country		
Documents submitted	package-data.xml application-body.xml AMSPECEPO-1.pdf\CLMS_CLEAN_1 10913_AMYU.pdf (6 p.) CLMS-HWA.pdf\CLMS_TRACKED_11 0913_AMYU.pdf (6 p.)	ep-euro-pct.xml epf1200.pdf (5 p.) OTHER-1.pdf\REQ_PACE_110913.pd f (1 p.)
Submitted by	CN=J. Lawrence 16522,O=Barker Brettell LLP,C=GB	
Method of submission	Online	
Date and time receipt generated	11 September 2013, 18:17 (CEST)	
Message Digest	AD:A2:1F:36:F2:07:E8:DB:1C:29:8D:EA:5F:CF:D6:3A:7D:47:DF:BB	

Correction by the EPO of errors in debit instructions filed by eOLF

Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated

software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

Claims

1. An aircraft, comprising:

a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

5 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:

10 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;

15 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;

20 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

25 wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

2. A method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising:

sensing a directional movement of the aircraft with a sensor carried by the aircraft, the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

5 controlling the directional movement of the aircraft with an actuator operably associated with the aircraft;

 providing a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

a model;

10 a lateral control architecture in data communication with the model;

a longitudinal control architecture in data communication with the model;

and

15 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;

20 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;

25 wherein the control system receives sensed directional movement 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.

3. 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;

5 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.

4. A method, comprising:

10 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.

15 5. The aircraft of claim 1, or the control system of claim 3, the aircraft or control system further comprising:

 a directional controller, the directional controller being manipulated by a pilot controlling the aircraft, the directional controller being in data communication with the control system;

20 or the method of claim 2 or of claim 4, the methods further comprising:

 commanding the flat yawing turns with a directional controller manipulated by a pilot controlling the aircraft, the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system.

25

6. The aircraft or control system of claim 5, the directional control architecture comprising:

 a directional heading control loop;

 a directional turn coordination control loop; and

30 a directional yaw rate control loop;

or either of the methods of claim 5, wherein the commanding of the flat yawing turns with the directional control architecture 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.

7. The aircraft or control system of claim 5, 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; or

either of the methods of claim 5, further comprising:

activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position, the directional control latch being operably associated with the directional control architecture.

8. The aircraft of claim 1 or control system of claim 5, the lateral control architecture comprising:

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

the method of claim 2 or of claim 4, wherein controlling the lateral direction of motion with the or a lateral control architecture comprises:

- 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.

9. The aircraft or control system of claim 8, 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; or

5 the method of claim 2 or of claim 4, further comprising:

controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft, the lateral controller being operably associated with the or a lateral control architecture.

10 10. The aircraft or control system of claim 9, 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 latch resets a lateral speed hold; or

either of the methods of claim 9, further comprising:

15 resetting a lateral speed hold with a lateral control hatch as the lateral controller is moved out of a detent position, the lateral control hatch being in data communication with the lateral control architecture.

20 11. The aircraft of claim 1 or the control system of claim 3, the longitudinal control architecture comprising:

a longitudinal forward speed control loop;

a longitudinal pitch angle control loop; and

a longitudinal pitch rate control loop; or

25 either of the methods of claim 10, wherein controlling the longitudinal direction of motion with the or a longitudinal control architecture comprises:

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.

12. The aircraft or the control system of claim 11, 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; or

either of the methods of claim 11, the longitudinal control architecture further comprising:

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture.

13. The aircraft or the control system of claim 12, 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 latch resets a longitudinal speed hold; or .

either of the methods of claim 12, further comprising:

resetting a longitudinal speed hold with a longitudinal control hatch as the longitudinal controller is moved out of a detent position, the longitudinal control hatch being in data communication with the longitudinal control architecture.

Claims

1. An aircraft, comprising:

a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

5 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:

10 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;

15 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;

20 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

25 wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

442. A method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising:

sensing a directional movement of the aircraft with a sensor carried by the aircraft, the directional movement having:

a longitudinal direction of motion; and

a lateral direction of motion;

5 controlling the directional movement of the aircraft with an actuator operably associated with the aircraft;

 providing a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

a model;

10 a lateral control architecture in data communication with the model;

a longitudinal control architecture in data communication with the model;

and

15 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;

20 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;

25 wherein the control system receives sensed directional movement 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.

| 3. 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;

5 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.

10 4. 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.

15 25. The aircraft of claim 1, or the control system of claim 3, the aircraft or control
system further comprising:

 a directional controller, the directional controller being manipulated by a pilot
controlling the aircraft, the directional controller being in data communication with the
control system;

20 or the method of claim 2 or of claim 4, 12. ~~The method of claim 11, the methods~~
further comprising:

 commanding the flat yawing turns with a directional controller manipulated by a
pilot controlling the aircraft, the directional controller being operably associated with a
directional control architecture, the directional control architecture being in data
25 communication with the control system.

30 63. The aircraft or control system of claim 25, the directional control architecture
comprising:

 a directional heading control loop;

 a directional turn coordination control loop; and

a directional yaw rate control loop;

~~or 13. either of the methods of claim 125, wherein the commanding of the flat yawing turns with the directional control architecture 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.

47. The aircraft ~~of claim 2~~ or control system of claim 5, 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; or

~~14. either of the methods of claim 125, further comprising:~~

activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position, the directional control latch being operably associated with the directional control architecture.

58. The aircraft of claim 1 or control system of claim 5, the lateral control architecture comprising:

a lateral sideward groundspeed control loop;

a lateral roll attitude control loop; and

a lateral roll rate control loop; or

~~the method of claim 2 or of claim 415. The method of claim 11, wherein controlling the lateral direction of motion with the~~ or a lateral control architecture comprises:

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.

69. The aircraft or control system of claim 58, 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; or

the method of claim 2 or of claim 416. ~~The method of claim 14,~~ further comprising:

controlling the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft, the lateral controller being operably associated with the or a lateral control architecture.

~~710.~~ The aircraft or control system of claim 69, 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 latch resets a lateral speed hold; or

either of the methods of claim 917. ~~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, the lateral control hatch being in data communication with the lateral control architecture.

~~811.~~ The aircraft of claim 1 or the control system of claim 3, the longitudinal control architecture comprising:

a longitudinal forward speed control loop;

a longitudinal pitch angle control loop; and

a longitudinal pitch rate control loop; or

~~18.~~ either of the methods of claim 170, wherein controlling the longitudinal direction of motion with the or a longitudinal control architecture comprises:

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.

5 | 912. The aircraft or the control system of claim 811, 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; or

10 | either of the methods of claim 1119. ~~The aircraft of claim 11,~~ the longitudinal control architecture further comprising:

controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture.

15 | 103. The aircraft or the control system of claim 912, 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

20 | longitudinal control latch resets a longitudinal speed hold; or.

either of the methods of claim 1220. ~~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 longitudinal control hatch being in data communication with the longitudinal control architecture.



Entry into the European phase (EPO as designated or elected Office)

To the European Patent Office

European application number	EP11862189.5
PCT application number	PCT/US2011/030498
PCT publication number	WO2012134460
Applicant's or representative's reference	JL69579P.EPP
International Filing Date	
International Searching Authority (ISA)	US
International Preliminary Examining Authority (IPEA)	not applicable
1. Applicant Indications concerning the applicant(s) are contained in the international publication or were recorded by the International Bureau after the international publication. Changes which have not yet been recorded by the International Bureau are set out here:	☒ ☐
2. Representative This is the representative who will be listed in the Register of European Patents and to whom notifications will be made Representative 1	Name: LAWRENCE, Mr John Company: Barker Brettell LLP Address of place of business: 100 Hagley Road Edgbaston Birmingham , West Midlands, B16 8QQ United Kingdom Telephone: +44 (0) 121 456 0000 Fax: +44 (0) 121 456 1368 e-mail: bham@barkerbrettell.co.uk
3. Authorisation An individual authorisation is attached. A general authorisation has been registered under No: A general authorisation has been filed, but not yet registered. The authorisation filed with the EPO as PCT receiving Office expressly includes the European phase.	☐ ☐ ☐ ☐
4. Request for examination Examination of the application under Art. 94 EPC is hereby requested. The examination fee is being (has been, will be) paid. Request for examination in an admissible non-EPO language: The applicant waives his right to be asked under Rule 70(2) EPC whether he wishes to proceed further with the application.	☒ ☐ ☒
5. Copies Additional copies of the documents cited in the supplementary European search report are requested. Number of additional sets of copies	☐
6. Documents intended for proceedings before the EPO Number of claims on entry into the European phase: 6.1 Proceedings before the EPO as designated Office (PCT I) are to be based on the following documents: the application documents published by the International Bureau (with all claims, description and drawings), where applicable with amended claims under Art. 19 PCT	13 ☐

unless replaced by the amendments attached.

Where necessary, clarifications should be attached as 'Other documents'

6.2 Proceedings before the EPO as elected Office (PCT II) are to be based on the following documents:

the documents on which the international preliminary examination report is based, including any annexes

unless replaced by the amendments attached.

Where necessary, clarifications should be attached as 'Other documents'

If the EPO as International Preliminary Examining Authority has been supplied with test reports, these may be used as the basis of proceedings before the EPO.

6.3 A copy of the results of the search carried out by the authority with which the previous application(s) whose priority is claimed was (were) filed is attached (R. 141(1) EPC).

6.4 The applicant waives his right to the communication under Rules 161(1) or (2) and 162 EPC.

7. Translations

Translations in one of the official languages of the EPO (English, French, German) are attached as crossed below:

* In proceedings before the EPO as designated or elected Office (PCT I + II):

Translation of the international application (description, claims, any text in the drawings) as originally filed, of the abstract as published and of any indication under Rule 13bis.3 and 13bis.4 PCT regarding biological material

Translation of the priority application(s) (to be filed only at the EPO's request,
Rule 53(3) EPC)

It is hereby declared that the international application as originally filed is a complete translation of the previous application (Rule 53(3) EPC)

** In addition, in proceedings before the EPO as designated Office (PCT I):*

Translation of amended claims and any statement under Art. 19 PCT, if the claims as amended are to form the basis for the proceedings before the EPO (see Section 6).

** In addition, in proceedings before the EPO as elected Office (PCT II):*

Translation of annexes to the international preliminary examination report

8. Biological material

The invention uses and/or relates to biological material deposited under Rule 31 EPC.

The particulars referred to in Rule 31(1)(c) EPC (if not yet known, the depositary institution and the identification reference(s)) [number, symbols, etc.] of the depositor) are given in the international publication or in the translation submitted in Section 7 on:

page(s) / line(s)

The receipt(s) of deposit issued by the depositary institution is (are) enclosed.

will be filed later.

Waiver of the right to an undertaking from the requester pursuant to Rule 33(2) EPC attached.

9. Nucleotide and amino acid sequences

The international application discloses nucleotide and/or amino acid sequences.

9.1 The sequence listing was filed under Rule 5.2(a) PCT, or furnished to the EPO as ISA under Rule 13ter.1(a) PCT, or is otherwise available to the EPO, in computer-readable format in accordance with WIPO ST.25.

9.2

The sequence listing is attached in computer-readable format in accordance with WIPO Standard ST.25

The sequence listing is attached in PDF format.

The sequence listing does not include matter which goes beyond the content of the application as filed.

10. Designation fees

All the contracting states party to the EPC at the time of filing of the international patent application and designated in the international application are deemed to be designated (see Article 79(1) EPC). The following states, which were contracting states to the EPC at the time of filing of the international application, are designated: AL AT BE BG CH&LI CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR	☒																																				
11. Extension of the European patent This application is deemed to be a request to extend the European patent application and the European patent granted in respect of it to all the non-contracting states to the EPC designated in the international application and with which extension agreements are in force on the date on which the international application is filed. However, the extension only takes effect if the prescribed extension fee is paid. It is currently intended to pay the extension fee for the following states: BA ME Note: Under the automatic debiting procedure, extension fees will only be debited for states indicated here, unless the EPO is instructed otherwise before expiry of the period for payment.	☒																																				
12. List of enclosed documents <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 5%;"></th> <th style="width: 35%;">Description of document</th> <th style="width: 35%;">Original file name</th> <th style="width: 25%;">Assigned file name</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1</td> <td>Combined Amendments</td> <td>CLMS_CLEAN_110913_AMYU.pdf</td> <td>AMSPECEPO-1.pdf</td> </tr> <tr> <td style="text-align: center;">2</td> <td>Amended claims with annotations</td> <td>CLMS_TRACKED_110913_AMYU.pdf</td> <td>CLMS-HWA.pdf</td> </tr> <tr> <td style="text-align: center;">3</td> <td>PACE request</td> <td>REQ_PACE_110913.pdf</td> <td>OTHER-1.pdf</td> </tr> </tbody> </table>				Description of document	Original file name	Assigned file name	1	Combined Amendments	CLMS_CLEAN_110913_AMYU.pdf	AMSPECEPO-1.pdf	2	Amended claims with annotations	CLMS_TRACKED_110913_AMYU.pdf	CLMS-HWA.pdf	3	PACE request	REQ_PACE_110913.pdf	OTHER-1.pdf																			
	Description of document	Original file name	Assigned file name																																		
1	Combined Amendments	CLMS_CLEAN_110913_AMYU.pdf	AMSPECEPO-1.pdf																																		
2	Amended claims with annotations	CLMS_TRACKED_110913_AMYU.pdf	CLMS-HWA.pdf																																		
3	PACE request	REQ_PACE_110913.pdf	OTHER-1.pdf																																		
13. Mode of payment: Debit from deposit account Currency The European Patent Office is hereby authorised, to debit from the deposit account with the EPO any fees and costs indicated on the fees page. Deposit account number Account holder	☒	EUR 28050004 Barker Brettell LLP																																			
14. Any refunds should be made to the following EPO deposit account: Number and account holder	☒	Barker Brettell LLP, 28050004																																			
15. Fees <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;"></th> <th style="width: 45%;">Description of document</th> <th style="width: 10%;">Factor/reduction applied</th> <th style="width: 15%;">Fee schedule</th> <th style="width: 20%;">Amount to be paid</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">15-1</td> <td>002 Fee for a European search - Applications filed on/after 01.07.2005</td> <td style="text-align: center;">-190</td> <td style="text-align: right;">1 165.00</td> <td style="text-align: right;">975.00</td> </tr> <tr> <td style="text-align: center;">15-2</td> <td>005e Designation fee - For all contracting States designated for applications filed on/after 01.04.2009</td> <td style="text-align: center;">1</td> <td style="text-align: right;">555.00</td> <td style="text-align: right;">555.00</td> </tr> <tr> <td style="text-align: center;">15-3</td> <td>006 Examination fee - For applications filed on/after 01.07.2005</td> <td style="text-align: center;">1</td> <td style="text-align: right;">1 555.00</td> <td style="text-align: right;">1 555.00</td> </tr> <tr> <td style="text-align: center;">15-4</td> <td>020 Filing fee - entry EP phase - online</td> <td style="text-align: center;">1</td> <td style="text-align: right;">115.00</td> <td style="text-align: right;">115.00</td> </tr> <tr> <td style="text-align: center;">15-5</td> <td>033 Renewal fee for the 3rd year</td> <td style="text-align: center;">1</td> <td style="text-align: right;">445.00</td> <td style="text-align: right;">445.00</td> </tr> <tr> <td colspan="3" style="text-align: right;">Total:</td> <td style="text-align: right;">EUR</td> <td style="text-align: right;">3 645.00</td> </tr> </tbody> </table>				Description of document	Factor/reduction applied	Fee schedule	Amount to be paid	15-1	002 Fee for a European search - Applications filed on/after 01.07.2005	-190	1 165.00	975.00	15-2	005e Designation fee - For all contracting States designated for applications filed on/after 01.04.2009	1	555.00	555.00	15-3	006 Examination fee - For applications filed on/after 01.07.2005	1	1 555.00	1 555.00	15-4	020 Filing fee - entry EP phase - online	1	115.00	115.00	15-5	033 Renewal fee for the 3rd year	1	445.00	445.00	Total:			EUR	3 645.00
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15-5	033 Renewal fee for the 3rd year	1	445.00	445.00																																	
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16. Annotations 16-1. Note (for EPO) (EP Phase)		PACE Request (EPO Form 1005) and explicit request for early processing of this application (John Lawrence) Accelerated prosecution of this application is requested. Furthermore, this annotation serves as an explicit request for early processing of this patent application according to Article 23(2) or Article 40(2) PCT, before the expiry of the 31-month period for European																																			

17. Signature(s) of applicant(s) or representative

Place: Birmingham,UK
Date: 11 September 2013
Signed by: GB, Barker Brettell LLP, J. Lawrence 16522
Capacity: (Representative)

Table for section 6 of Form 1200.3

In accordance with the Notice from the European Patent Office dated 26 January 2009 concerning the 2009 fee structure (OJ EPO 2009, 118, and Guidelines for Examination in the EPO, April 2009, A-III, 13.2), the amount of the additional fee (Art. 2, item 1a, Rules relating to Fees) for the pages of this European patent application is calculated as follows:

Documents intended for proceedings before the EPO (R. 159 (1) (b) EPC) and for calculating the additional fee (Art. 2, item 1a, RFees):

	Page(s) from ... to ...	Number of pages
Description: International application as published	1-13	13
Claims: Amendments filed on entry into European phase	13-19	7
Drawings: International application as published	20-28	8
Abstract: Default count: one page		1
Total number of pages		29
Fee-exempt pages (Art. 2, item 1a, RFees)		-35
Number of pages to be paid for		0
(x 14 EUR per page)		
Total amount payable	EUR	0



Bell Helicopter Textron Inc.
P.O. Box 482
Fort Worth, TX 76101
ETATS-UNIS D'AMERIQUE

**For any questions about
this communication:**

Tel.: +31 (0)70 340 45 00

Date

09.08.13

Reference	Application No./Patent No. 11862189.5 - 1802 PCT/US2011030498
Applicant/Proprietor Bell Helicopter Textron Inc.	

Entry into the European phase before the European Patent Office

The following information describes the procedural steps required for entry into the European phase before the European Patent Office (EPO). You are advised to read it carefully because failure to take the necessary action in due time can lead to a loss of rights.

1. The above mentioned international patent application has been given the **European application No. 11862189.5**.
2. Applicants **without a residence or their principal place of business** in an EPC Contracting State may themselves initiate European processing of their international applications, provided they do so before expiry of the 31st month from the priority date.

During the European phase before the EPO as designated or elected Office, however, such applicants **must** be represented by a professional representative (Art. 133(2) and Art. 134(1) and (8) EPC).

Where, at the expiry of the time period laid down in Rule 163(5) EPC, the requirements of Article 133(2) EPC have not been complied with, the European patent application will be **refused**, pursuant to Rule 163(6) EPC.

Please note that a professional representative authorised to act before the EPO and who acted for the applicant during the international phase does not automatically become the representative for the European phase. Applicants are therefore strongly advised to appoint in good time any representative they wish to initiate the European phase for them; otherwise the EPO has to send all communications directly to the applicant.

3. Applicants **with a residence or their principal place of business** in an EPC Contracting State are not obliged to appoint for the European phase a professional representative authorised to act before the EPO. However, in view of the complexity of the procedure it is recommended that they do so.
4. Applicants and professional representatives are also strongly advised to initiate the European phase using **EPO Form 1200**. It is available free of charge from the EPO or via the EPO website at **www.epo.org**. Similarly, it can be or generated with the Online Filing software, obtainable free of charge from the EPO (**www.epoline.org**) The use of the form is not compulsory.

-
5. Where the EPO acts as designated or elected Office (Art. 22(1) and (3) and 39(1) PCT), to enter the European phase before the EPO, the **following acts** must be performed by the applicant within **31 months** from the date of filing of the international application or (where applicable) the earliest priority date:
- a) Supply a translation of the international application into an EPO official language, if the International Bureau did not publish the application in such language (Art. 22(1) PCT and R. 159(1)(a) EPC);
 - b) Specify the application documents, as originally filed or as amended, on which the European grant procedure is to be based (R. 159(1)(b) EPC);
 - c) Pay the filing fee and, where applicable, the additional fee for a European patent application comprising more than 35 pages (R. 159(1)(c) EPC, Art. 2, items 1, 1a Rules relating to Fees);
 - d) Pay the search fee where a supplementary European search report has to be drawn up (R. 159(1)(e) EPC);
 - e) Pay the designation fee if the time limit laid down in Rule 39(1) EPC (i.e. six months after publication of the international search report) has expired before the 31-month period pursuant to Rule 159(1) EPC (R. 159(1)(d) EPC);
 - f) File the written request for examination and pay the examination fee if the time limit laid down in Rule 70(1) EPC has expired before the 31-month period pursuant to Rule 159(1) EPC (R. 159(1)(f) EPC);
 - g) Pay the renewal fee in respect of the third year, if the fee has fallen due (see Rule 51(1) EPC) before expiry of the 31-month period pursuant to Rule 159(1) EPC (R. 159(1)(g) EPC);
 - h) File, where applicable, the certificate of exhibition referred to in Article 55(2) and Rule 25 EPC (R. 159(1)(h) EPC);
 - i) Pay the claims fees for the sixteenth and each subsequent claim when the application documents on which the European grant procedure is to be based comprise more than fifteen claims (R. 162(1) EPC). For applications entering the European phase on or after 1 April 2009, a higher amount is payable for the 51st and each subsequent claim (Decision of the Administrative Council of 14 December 2007 amending the Rules relating to Fees, OJ EPO 2008, 10).

If either the translation of the international application or the request for examination is not filed in time, or if the filing fee, the additional fee, the search fee, the designation fee or the examination fee is not paid in due time, the application shall be deemed to be withdrawn (R. 160(1) EPC).

6. Payment of fees

An up-to-date guidance for the payment of fees, expenses and prices and a list of the euro accounts of the European Patent Organisation are published in each issue of the Official Journal of the EPO. The guidance includes inter alia a reference to the latest version of the Schedule of fees and expenses where the amounts of fees are set out.

The Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, is also available on the EPO website (www.epo.org) and can be found under **www.epo.org/schedule-of-fees**, which allows the viewing, downloading and searching for individual fee amounts, both current and previous.

Applicants should always check the fee amounts applying at the time of payment.

Payments can be validly made by any person. Permissible methods of payment are laid down in Article 5 Rules relating to Fees. Please note that payment cannot be made by cheque sent to the EPO.

For information on the calculation of the additional fee for applications comprising more than 35 pages, see Notice from the European Patent Office dated 26 January 2009 concerning the 2009 fee structure (OJ EPO 2009, 118), Notice supplementing the notice from the European Patent Office dated 26 January 2009 concerning the 2009 fee structure (OJ EPO 2009, 338) and Guidelines for Examination in the EPO, April 2010, A-III, 13.2.

For an overview of search and examination fees, see Notice from the European Patent Office dated 6 February 2012 (OJ EPO 2012, 212). Fee information is also published on the EPO website under www.epo.org/fees.

7. Restoration of priority right

Where the international application contains a priority claim to an earlier application and it has been filed within two months from the expiration of the 12-month priority period, a request for restoration before the EPO as designated Office (R. 49*ter*.2 PCT) applies under the following circumstances:

- a) No request for restoration filed before the receiving Office (RO) during the international phase (R. 26*bis*.3 PCT)
- b) Negative decision by the RO irrespective of the criterion applied (due care/ unintentionality)
- c) Positive decision by the RO based on the unintentionality criterion.

For a request to be admissible, it must be filed and the requisite fee must be paid (R. 49*ter*.2(b)(iii) and R. 49*ter*.2(d) PCT) within one month from the applicable time limit under Article 22 PCT for entering the regional phase (R. 49*ter*.2(b)(i) PCT). The request for restoration also needs to state the reasons for the failure to file the international application within the priority period (Rule 49*ter*.2(b)(ii) PCT).

- 8. If the applicant had appointed a representative during the application's international phase, the present Form will be sent to the representative, asking him to inform the applicant accordingly.
All subsequent communications will be sent to the applicant, or - if the EPO is informed of his appointment in time - to the applicant's European representative.
- 9. For more details about time limits and procedural acts before the EPO as designated or elected Office, see the EPO brochure "How to get an European patent", Guide for applicants - Part 2, PCT procedure before the EPO - "Euro-PCT" (EPO PCT Guide). This brochure, the list of professional representatives before the EPO, Form 1200 and details of the latest fees are available on the Internet under <http://www.epo.org>.

10. Programme for accelerated prosecution of European patent applications - "PACE"

Applicants wishing to accelerate proceedings before the EPO as designated or elected Office may request accelerated search and/or examination under the PACE programme (Notice from the European Patent Office dated 4 May 2010 concerning the programme for accelerated prosecution of European patent applications - "PACE", OJ EPO 2010, 352). To be as effective as possible, this should preferably be requested immediately on entry into the European phase.

Receiving Section



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

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(71) Applicant (for all designated States except US):

BELL HELICOPTER TEXTRON INC. [US/US]; P.O. Box 482, Fort Worth, TX 76101 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): CHRISTENSEN, Kevin, Thomas [US/US]; 3905 Branchwood Drive, Plano, TX 75093 (US). SHUE, Shyhyng, Jack [US/US]; 2809 Woodland Hills Drive, Grapevine, TX 76051 (US). CAU-DILL, Troy, Sheldon [US/US]; 6195 Oak Hollow Drive, Burleson, TX 76028 (US).

(74) Agent: WALTON, James, E.; Law Offices of James E.

Walton, P.L.L.C., 1169 N. Burleson Blvd., Suite 107-328, Burleson, TX 76028 (US).

(81) Designated States (unless otherwise indicated, for every

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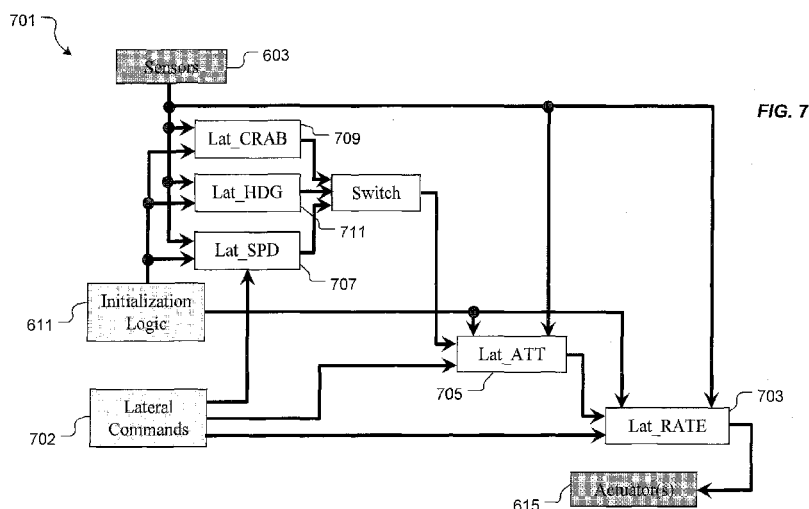
Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS



(57) **Abstract:** An aircraft and method to control flat yawing turns of the aircraft while maintaining a constant vector across a ground surface. The aircraft includes a control system in data communication with control actuators, a lateral control architecture, a longitudinal control architecture, and an initialization command logic. The lateral control architecture controls the aircraft in the lateral direction, while the longitudinal control architecture controls the aircraft in the longitudinal direction. The initialization command logic automatically activates the lateral control architecture and the longitudinal control architecture to maintain a constant vector across the ground whenever a directional control input is made at low speed.

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FLIGHT CONTROL LAWS FOR CONSTANT VECTOR FLAT TURNS

Technical Field

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.

Description of the Prior Art

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.

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.

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.

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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.

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

Brief Description of the Drawings

The novel features believed characteristic of the application are set forth in the appended claims. However, the application itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood with 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;

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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;

5 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

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

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
15 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.

Description of the Preferred Embodiment

20 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. As a result of this auto-moding logic, the

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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.

5 The auto-moding logic 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
10 having to use cockpit switches to change modes.

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
15 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.

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
20 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.
25

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

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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.

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.

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.

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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 pedal turn is applied to rotate aircraft 201 in a forward heading with a pedal 203. In the preferred embodiment, pedal 203 is a pedal 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 pedal 203. For purposes of this invention, a lateral controller, longitudinal controller, and directional controller are characterized as pedal 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.

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 pedal turn is applied to rotate aircraft 201 such that the forward flight of aircraft 201 changes to a sideward flight heading.

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

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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.

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.

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 a minimum, thus stabilizing the system.

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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-initialize inactive loops in order to eliminate control jumps when switching between the loops to provide seamless and transient free mode changes.

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.

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.

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,

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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).

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".

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.

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

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

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.

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

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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).

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"

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.

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.

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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.

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.

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:

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

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

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.

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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.

Both longitudinal speed hold 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/sec^2).

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

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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.

5 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.

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Claims

1. 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.

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2. The aircraft of claim 1, the aircraft further comprising:
a directional controller, the directional controller being manipulated by a pilot controlling the aircraft, the directional controller being in data communication with the control system.

3. The aircraft of claim 2, the directional control architecture comprising:
a directional heading control loop;
a directional turn coordination control loop; and
a directional yaw rate control loop.

4. The aircraft of claim 2, 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 aircraft 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 aircraft 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 aircraft of claim 6, further comprising:
a lateral control latch in data communication with the control system;

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wherein, as the lateral controller is moved out of a detent position, the lateral control latch resets a lateral speed hold.

8. The aircraft 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 aircraft 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 aircraft 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. 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:

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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.

12. The method of claim 11, the method further comprising:

commanding the flat yawing turns with a directional controller manipulated by a
pilot controlling the aircraft, the directional controller being operably associated with a
directional control architecture, the directional control architecture being in data
communication with the control system.

13. The method of claim 12, wherein the commanding of the flat yawing turns with
the directional control architecture 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.

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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, the directional control latch being operably associated with the directional control architecture.

15. The method of claim 11, wherein controlling the lateral direction of motion with the lateral control architecture comprises:

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 the lateral direction of motion with a lateral controller manipulated by a pilot controlling the aircraft, the lateral controller being operably associated with the lateral control architecture.

17. The aircraft of claim 16, further comprising:

resetting a lateral speed hold with a lateral control latch as the lateral controller is moved out of a detent position, the lateral control latch being in data communication with the lateral control architecture.

18. The method of claim 17, wherein controlling the longitudinal direction of motion with the longitudinal control architecture comprises:

communicating longitudinal motion data through a longitudinal forward speed control loop;

communicating longitudinal motion data through a longitudinal pitch angle control loop; and

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communicating longitudinal motion data through a longitudinal pitch rate control loop.

19. The aircraft of claim 11, the longitudinal control architecture further comprising:
controlling the longitudinal direction of motion with a longitudinal controller manipulated by a pilot controlling the aircraft, the longitudinal controller being operably associated with the longitudinal control architecture.

20. The aircraft of claim 19, further comprising:
resetting a longitudinal speed hold with a longitudinal control latch as the longitudinal controller is moved out of a detent position, the longitudinal control latch being in data communication with the longitudinal control architecture.

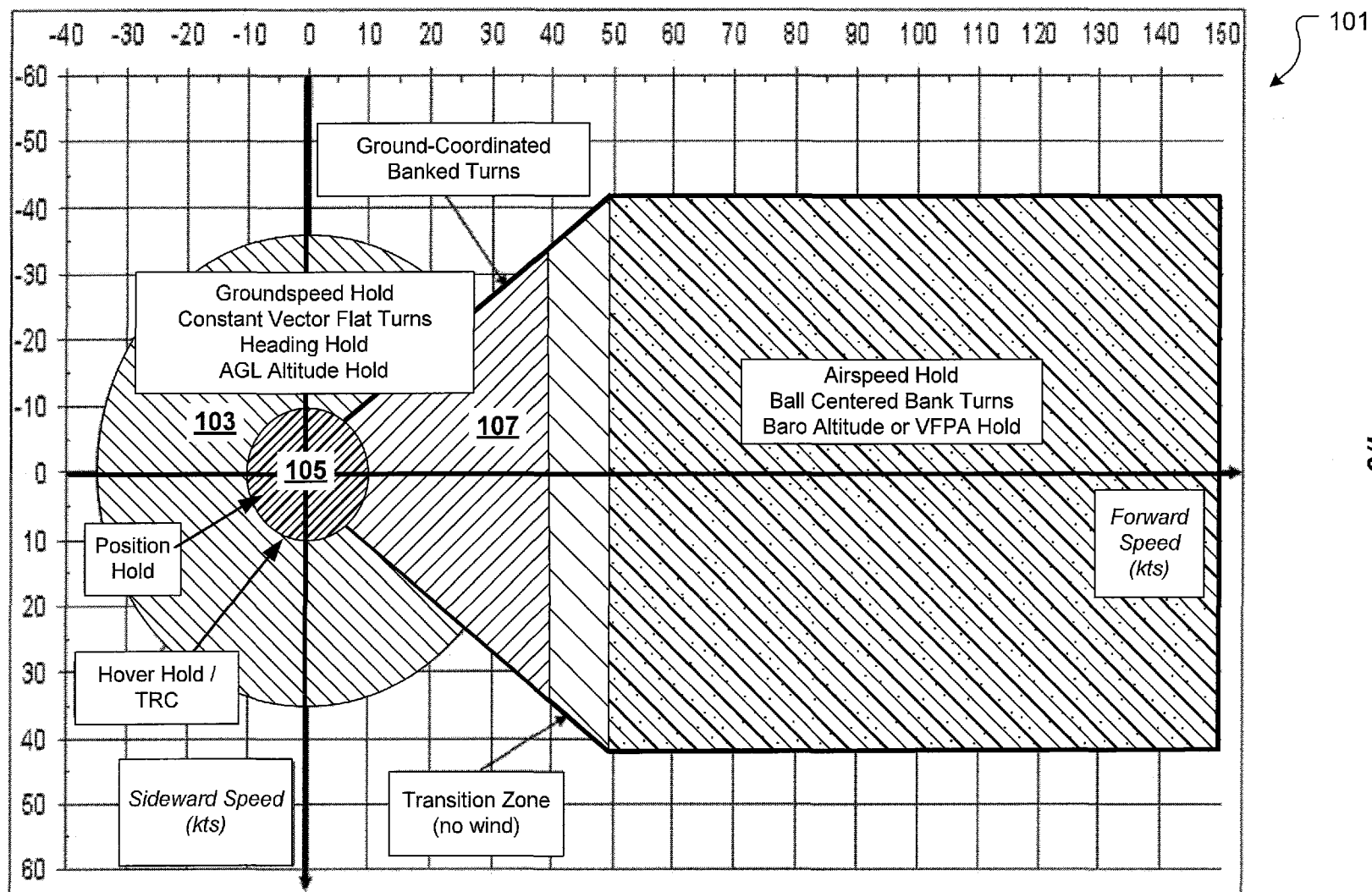


FIG. 1

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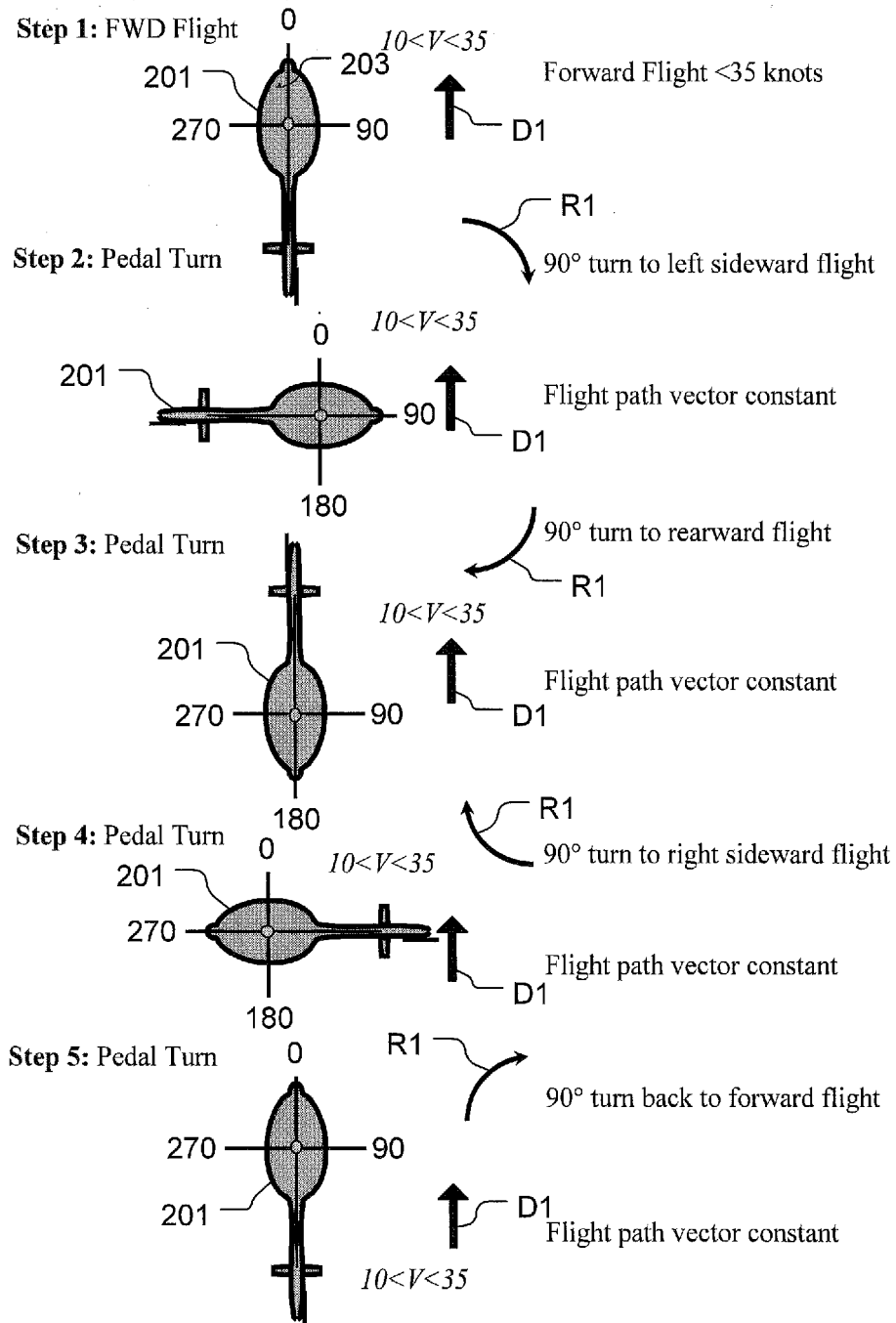


FIG. 2

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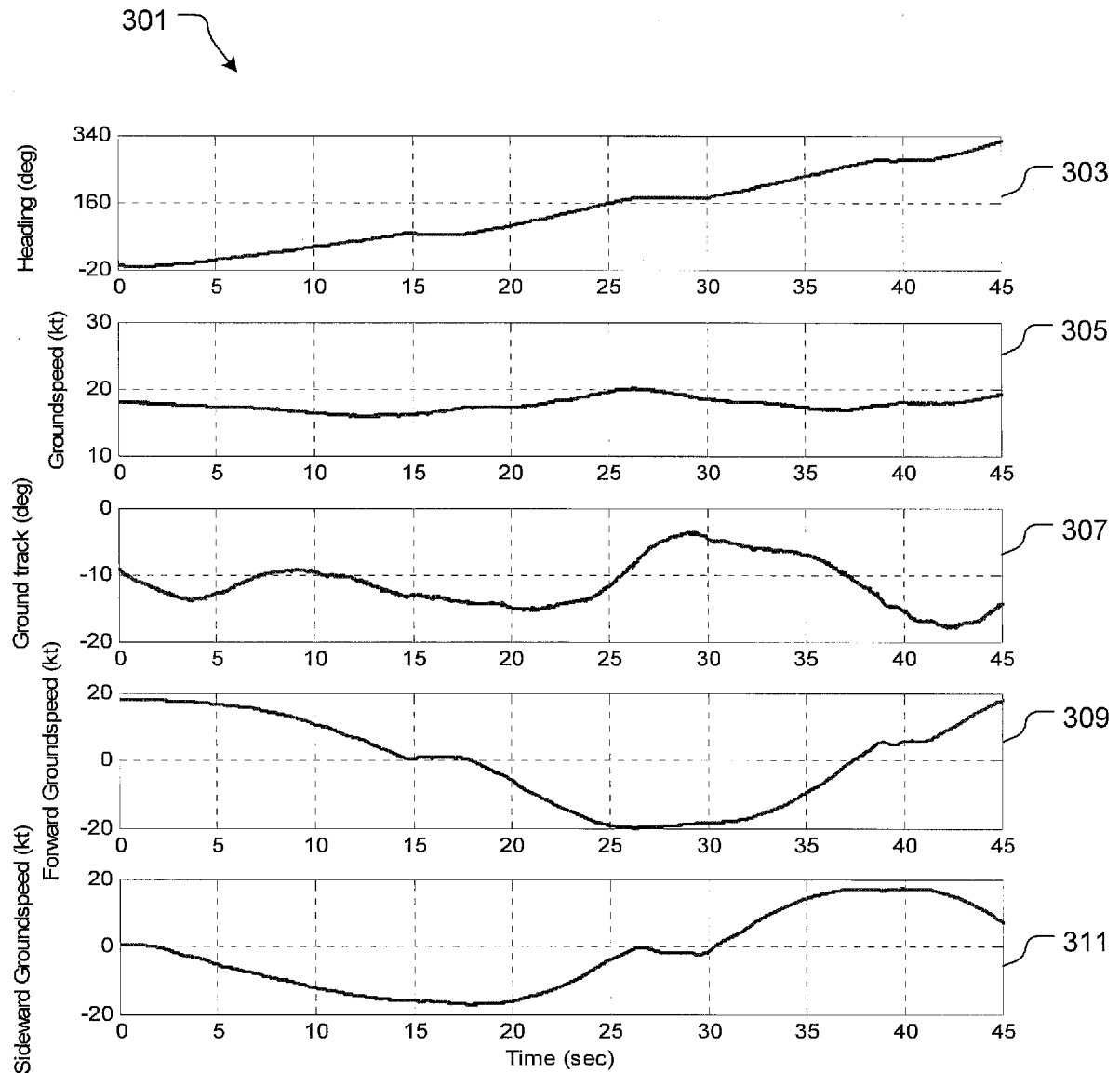


FIG. 3

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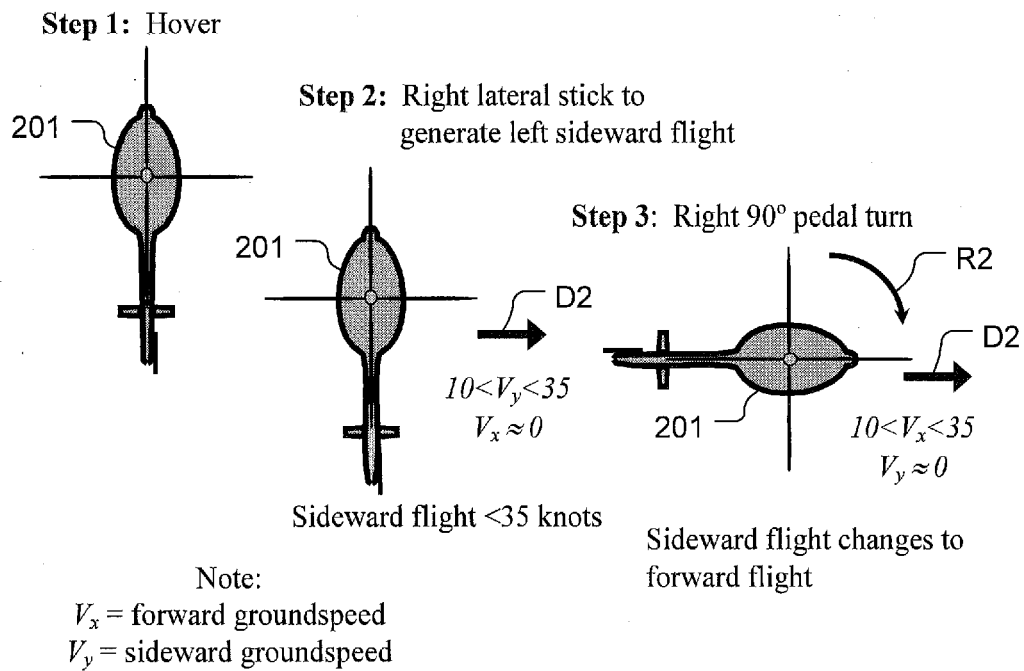


FIG. 4

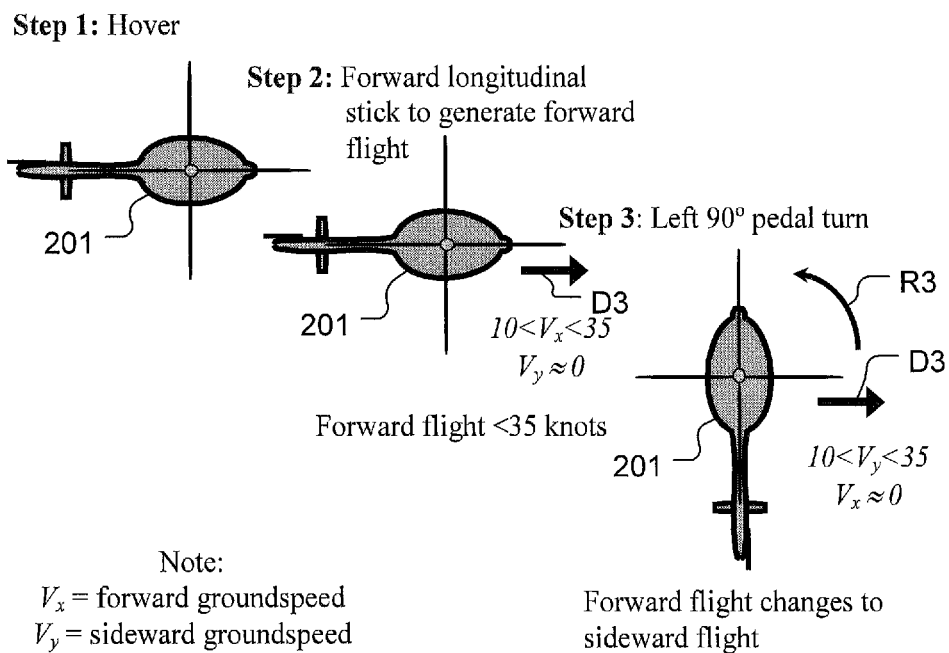


FIG. 5

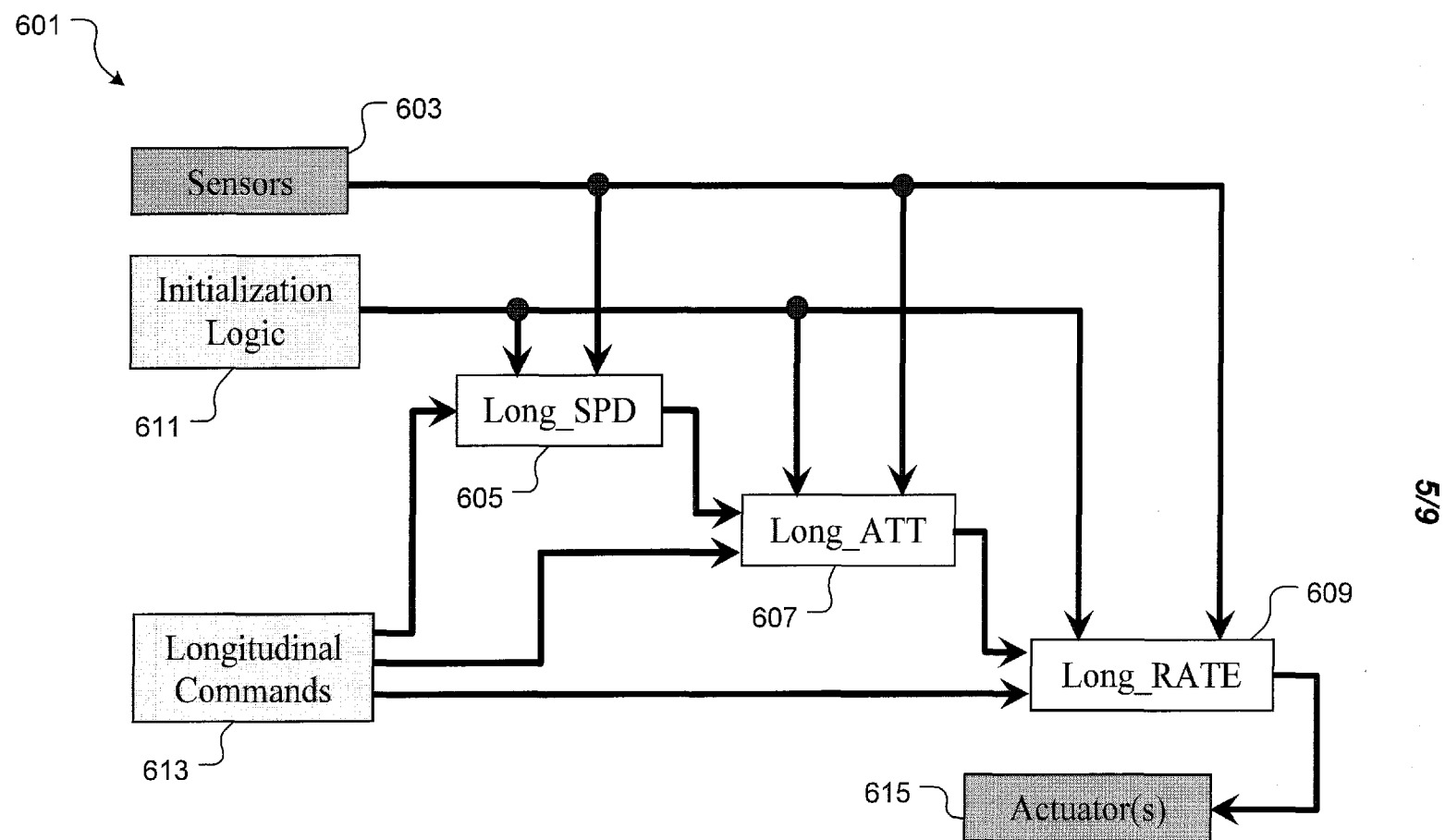


FIG. 6

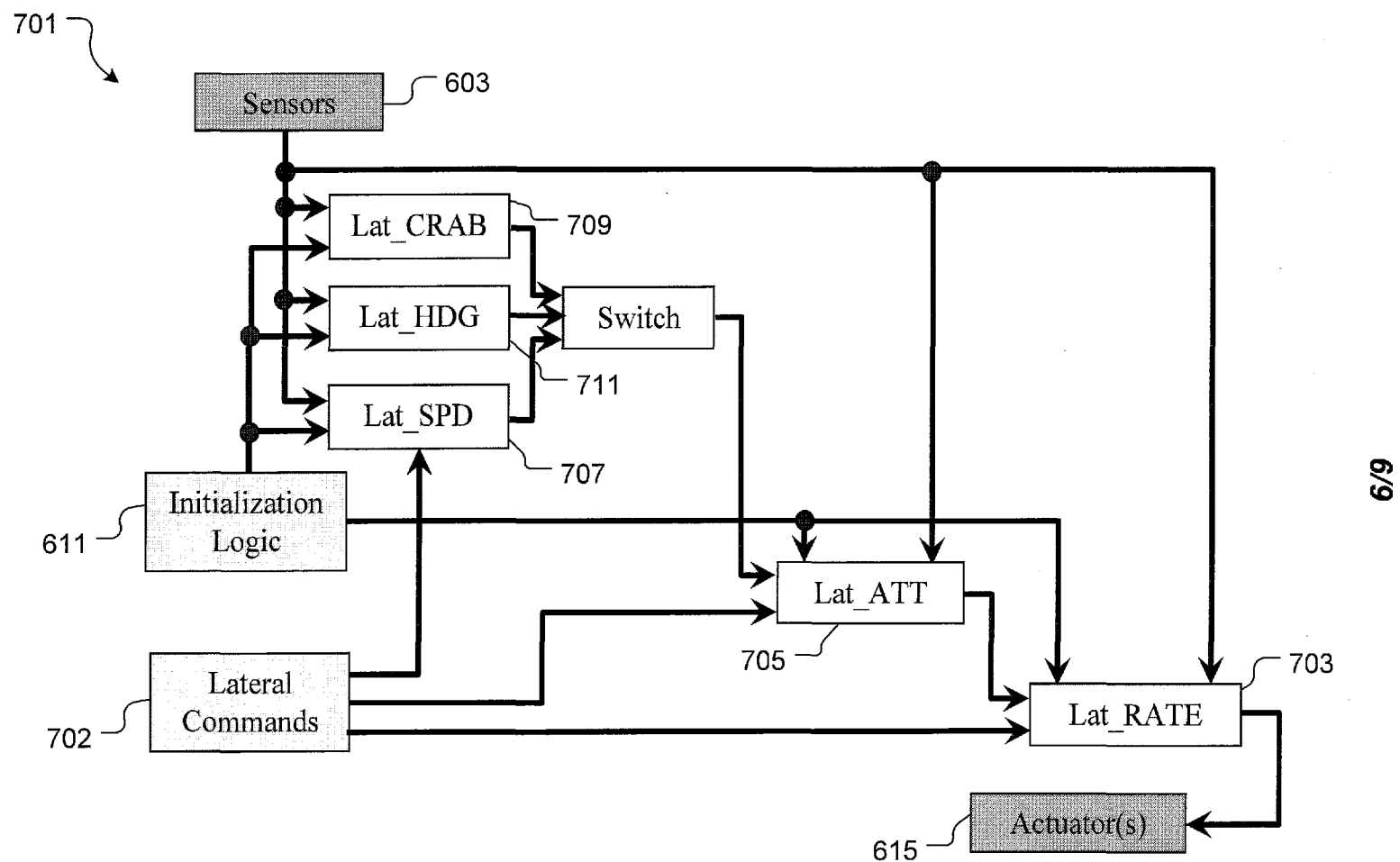


FIG. 7

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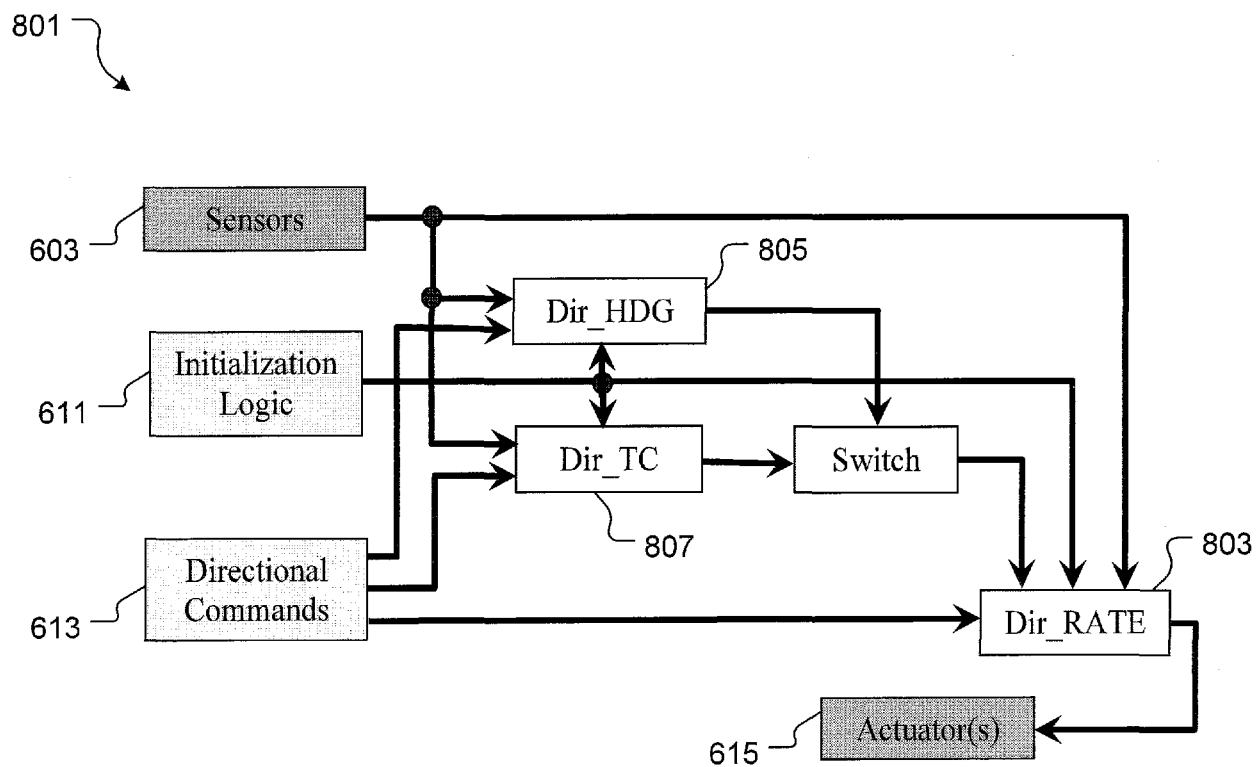


FIG. 8

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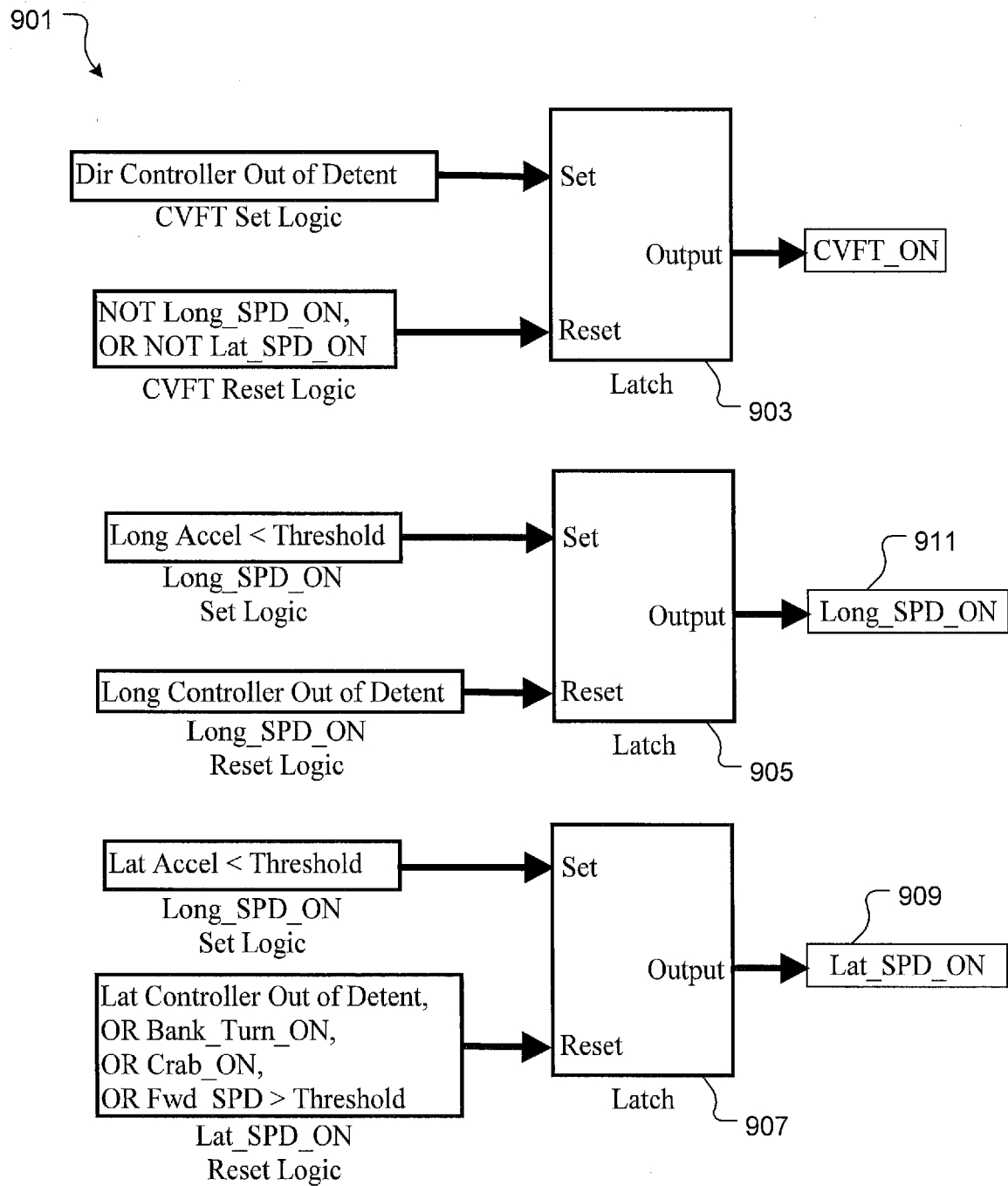


FIG. 9

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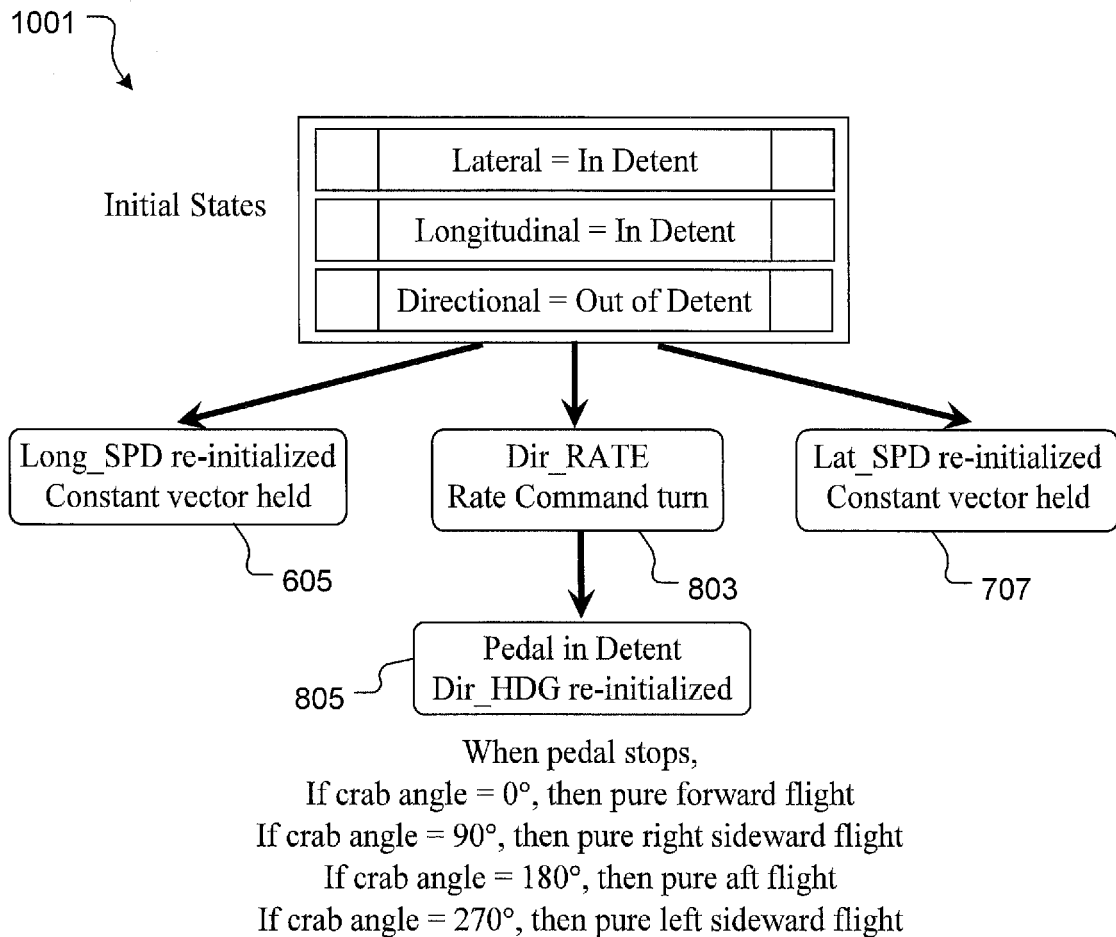


FIG. 10