



(86) Date de dépôt PCT/PCT Filing Date: 2005/06/14
(87) Date publication PCT/PCT Publication Date: 2006/12/21
(45) Date de délivrance/Issue Date: 2017/09/05
(85) Entrée phase nationale/National Entry: 2007/12/06
(86) N° demande PCT/PCT Application No.: SE 2005/000915
(87) N° publication PCT/PCT Publication No.: 2006/135284

(51) Cl.Int./Int.Cl. *G09B 9/44* (2006.01),
G09B 9/042 (2006.01), *G09B 9/052* (2006.01)

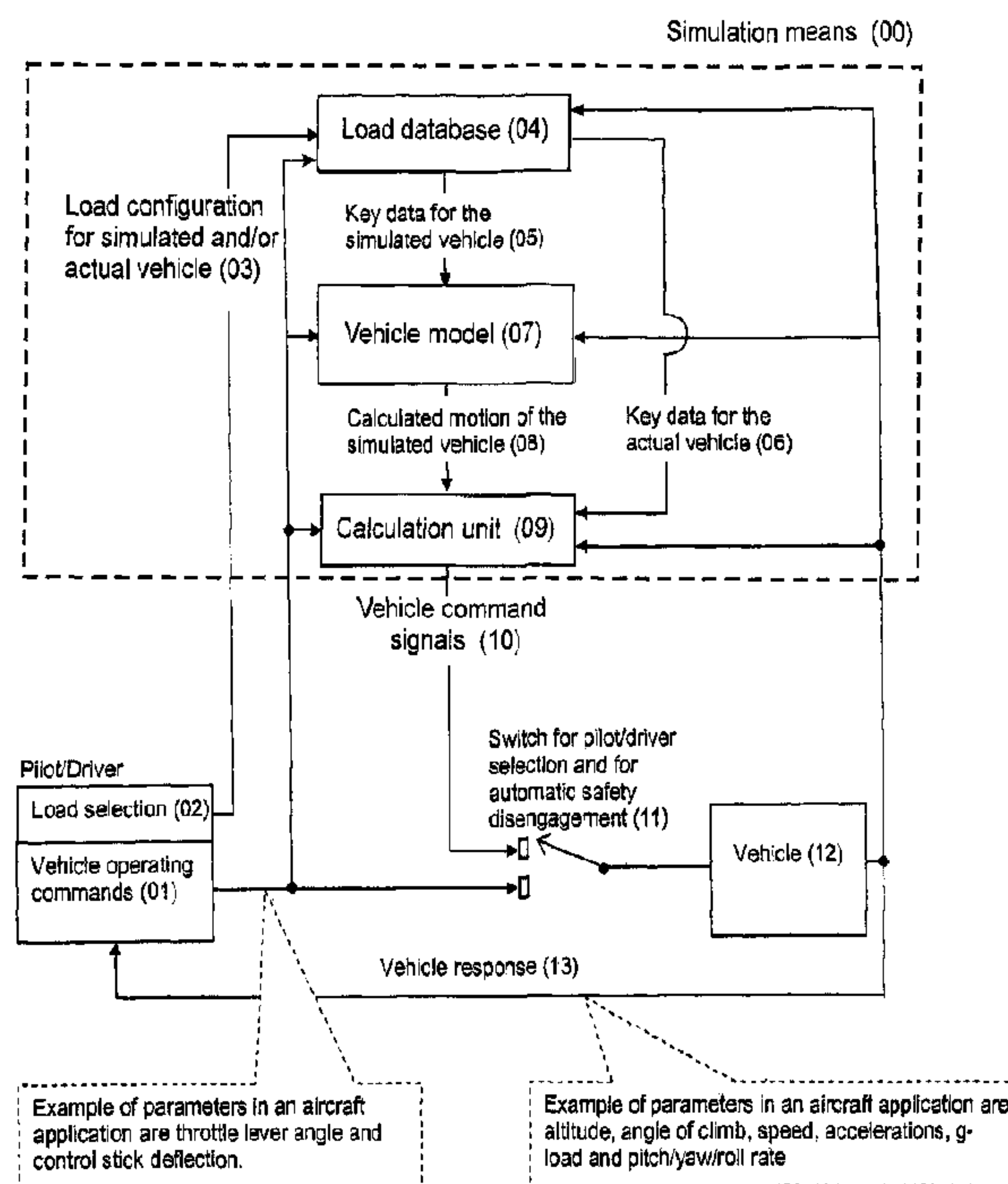
(72) Inventeurs/Inventors:
JOHNSSON, THOMAS, SE;
LUNDBLADH, ANDERS, SE;
RING, DAN, SE;
HANNIUS, OLOF, SE

(73) Propriétaire/Owner:
GKN AEROSPACE SWEDEN AB, SE

(74) Agent: DENNISON ASSOCIATES

(54) Titre : METHODE POUR ENTRAINER UNE PERSONNE TOUT EN PILOTANT UN VEHICULE

(54) Title: A METHOD FOR TRAINING A PERSON WHILE OPERATING A VEHICLE



(57) Abrégé/Abstract:

A method for training a person while operating a vehicle (12). The vehicle has a control system for receiving vehicle operating commands (01) from said person for controlling the vehicle (12). A means (00) is provided for simulating a state of the vehicle (12) and/or the environment to which the vehicle is subjected, the simulated state being a possible real state of the vehicle and/or the environment which is different from the actual state of the vehicle and/or the environment. The vehicle operating commands (01) and the simulation means (00) are used for calculating vehicle command signals (10). The vehicle command signals (10) are used for controlling the vehicle so as to cause the vehicle (12) to respond to the vehicle operating commands (01) in a way that corresponds to the state simulated by the simulation means (00) instead of the actual state of the vehicle and/or the environment.



(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
21 December 2006 (21.12.2006)

PCT

(10) International Publication Number
WO 2006/135284 A1

(51) International Patent Classification:

G09B 9/44 (2006.01) **G09B 9/052** (2006.01)
G09B 9/042 (2006.01)

Olof [SE/SE]; Tunhemsvägen 74, S-461 43 Trollhättan (SE).

(21) International Application Number:

PCT/SE2005/000915

(74) Agent: **FRÖHLING, Werner**; Volvo Technology Corporation, Corporate Patents, 06820, M1.7, SE-405 08 Göteborg (SE).

(22) International Filing Date: 14 June 2005 (14.06.2005)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): **VOLVO AERO CORPORATION** [SE/SE]; S-461 81 Trollhättan (SE).

(72) Inventors; and

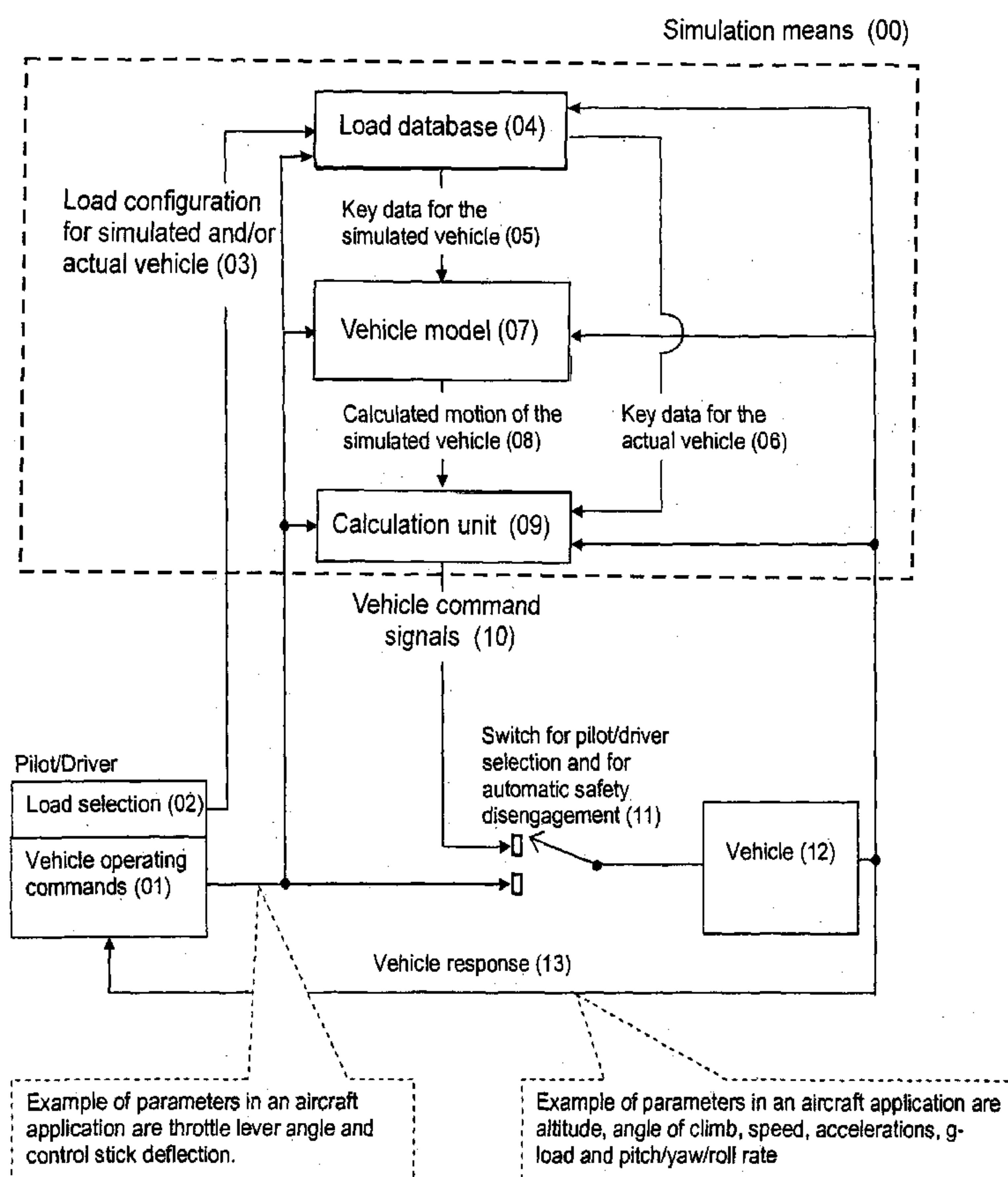
(75) Inventors/Applicants (for US only): **JOHNSSON, Thomas** [SE/SE]; Bergkullevägen 432, S-461 67 Trollhättan (SE). **LUNDBLADH, Anders** [SE/SE]; Brilljantvägen 8, S-461 73 Trollhättan (SE). **RING, Dan** [SE/SE]; Österlånggatan 12B, S-461 31 Trollhättan (SE). **HANNIUS,**

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,

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(54) Title: A METHOD TRAINING A PERSON WHILE OPERATING A VEHICLE



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FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO,
SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN,
GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *with international search report*

WH-13268CA
SN 2,611,282

A method for training a person while operating a vehicle

FIELD OF THE INVENTION

5 The present invention relates to a method for training a person while operating a vehicle.

The invention is applicable to different types of vehicles, in particular air vehicles such as aircraft for training pilots. Although the invention will be exemplified by describing an aircraft application, the invention can also be applied to other vehicles, such as cars, boats,
10 trains etc. Thus, by the word "vehicles" is meant airborne vehicles, land vehicles as well as marine vehicles.

BACKGROUND OF THE INVENTION

15 Training of pilots includes flying with heavily loaded aircraft. A modern aircraft can carry loads weighing at least as much as the weight of the empty aircraft. Therefore, such flights are expensive to perform because the engines have to run at high rating and fuel consumption is high. In addition, the high engine rating means significantly increased engine wear resulting in higher cost for engine maintenance. Furthermore, the stress
20 levels (fatigue) of the aircraft structure are higher in a loaded aircraft resulting in a shorter life span and higher maintenance cost. Training with heavily loaded aircraft also means a flight safety hazard, in particular during the take off phase. A heavy aircraft has less margins and in case of an engine fault, a bird strike or any other incident there will be a higher risk for a catastrophic situation which could result in serious injuries among the
25 crew.

The high cost and risk for training with heavily loaded aircraft often leads to the fact that such training is avoided and thus, the pilots receive less realistic training than desired.

30 Ground-based flight simulators are sometimes used for the above-mentioned training but in many aspects they cannot provide sufficiently realistic conditions.

Another type of training which provides more realistic situations is the use of airborne simulation systems used in real aircraft during flying. Such simulation systems use
35 software for imposing power output limits on an engine for simulating an engine failure. A method for simulating an engine failure in a multiple-engine aircraft is described in US 2002/0133322. The engine failure is simulated by placing a software output limiter on one or more engines. This could be combined with fictitious gauge readings on the pilot's

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instrument panel. However, such a method, which only means that there is an option mode conferring an impaired performance of the engine which is usable for simulating a specific engine failure, does not support general training with heavily loaded aircraft of the type discussed above.

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THE OBJECT OF THE INVENTION AND SUMMARY OF THE INVENTION

The present invention provides a method of the kind referred to in the introduction, which method makes it possible to train persons, such as aircraft pilots, to operate a vehicle during trying conditions in a realistic and safe way and at reasonable costs. In particular the method allows training for a simulated load state while operating the vehicle.

By such a method, a pilot/driver of the vehicle can experience the behaviour of the vehicle in a certain operating state without actually operating the vehicle in this certain state. Realistic training can be performed to a lower cost while still using a real vehicle. For example, the vehicle can be selected to behave as if the load configuration was different from the actual conditions. In other words; a simulation of a heavily loaded aircraft can be performed by flying an unloaded (light) aircraft. The invention can cause an unloaded and light aircraft to behave like it really was loaded and heavy. This in turn can save costs and improve safety.

The invention also relates to a training system for training a person while operating a vehicle in a modified manner to simulate changes in the simulated load state of the vehicle.

The method and system according to the invention may be used for simulating many different load states of the vehicle. The term "different load states" does not comprise different designs of the vehicle, or other kinds of vehicle, beyond modifications associated to the loading of the vehicle. As an example, the real state of an air vehicle could be an unloaded state and the simulated state of the air vehicle could be a state where the same air vehicle is loaded with weapons, such as missiles or

-continued on page 3-

similar. In another example a simulated fuel quantity is different from the actual fuel quantity carried by the vehicle.

5 Further examples of simulated states are the simulation of a transient disturbance of an air vehicle due to releasing loads although no actual loads are released, and the simulation of special wind and temperature conditions although the actual weather is different. The consequence of the simulated states is that the weight of the simulated vehicle is different from the actual weight of the vehicle, that the centre of gravity of the simulated vehicle is different from the actual centre of gravity of the vehicle and/or
10 that the moment of inertia the simulated vehicle is different from the actual moment of inertia of the vehicle. Further consequences may be that the relationship between the angle of attack and sideslip and the drag and lift of the simulated vehicle is different from the actual relationship between said angles and the drag and lift of the vehicle.

15 Particularly, the method according to the invention may be used for training a pilot/driver by the simulation of a state, which state is created by controlling dynamic properties of the vehicle and/or controlling an engine of the vehicle, such as the position of one or more air vehicle control surfaces and/or the setting of engine thrust and/or thrust vectoring.

20 According to a preferred embodiment of the invention, the motion of the vehicle in the simulated state is calculated in a first step by using a vehicle model and the vehicle operating commands as input, and then the vehicle command signals are calculated in a second step by using the calculated motion of the vehicle in the simulated state as input
25 to the calculation unit. Hereby, the controller for training mode operation can be designed using the controller for normal mode operation and the equations of motion.

The vehicle model, which can handle different load configurations and environmental conditions for instance, can be either in its simplest form a tabulated vehicle
30 description, but preferably a real time dynamic model for the vehicle motion based on the equations of motion.

The calculated vehicle command signals used for controlling the vehicle are ordinary vehicle control signals and any additional vehicle control signals produced by the
35 training system during training mode only. However, in both cases the calculated vehicle command signals are based on the vehicle operating commands and designed to cause the vehicle to respond to the vehicle operating commands in a way that corresponds to the state simulated by the vehicle model instead of the actual state of the vehicle and/or the environment.

A control unit comprised in the simulation system may be achieved based on known electrical and/or mechanical control components and corresponding software. A computer program comprising an instruction set stored in an internal memory of the computer may be used to instruct a processor for accomplishing the steps of the method when the instruction set is executed in the computer. The computer program can be provided at least partly via a network such as the Internet. The control unit may be designed for receiving a computer readable medium having a stored program or data thereon intended to cause the computer to control the steps of the method according to the invention.

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Other advantageous features and functions of different embodiments of the invention according to the invention appear from the following detailed description and dependent claims.

15 BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a more detailed description of preferred embodiments of the invention provided merely as non-limiting examples.

20 In the drawings:

Fig. 1 is a block diagram schematically illustrating one embodiment of a simulation system for carrying out the method according to the invention,

25 Fig. 2 is a variant of the system in figure 1 adapted for an aircraft,

Fig. 3 is a view of an aircraft illustrating the forces acting on an aerial vehicle while flying,

30 Fig. 4 is a graph illustrating the acceleration and the velocity of a loaded and unloaded aircraft for a certain pilot command, and

35 Fig. 5 is a graph illustrating the acceleration of a loaded aircraft as in figure 4 and the acceleration of an unloaded aircraft controlled by the system and the method according to the invention for simulating a loaded aircraft (to the left), and pilot PLA-command (Power Lever Angle) and calculated actual engine PLA-command (to the right).

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A general vehicle simulator system for carrying out the method according to the invention is illustrated for a general vehicle in figure 1. A pilot/driver normally issues vehicle operating commands 01 for controlling a vehicle 12 and uses the vehicle response 13 as feedback. The vehicle may be provided with a propulsion system comprising one or more engines. In many applications the vehicle is provided with control surfaces. The engines and the control surfaces are to be controlled by the pilot/driver by means of the vehicle operating commands received by a control system of the vehicle.

Examples of vehicle operating command parameters in an aircraft application are power lever angle and control stick deflection. Examples of vehicle response parameters in an aircraft application are altitude, angle of climb, speed, accelerations, g-load and pitch/yaw/roll rates. The system comprises a switch 11 or similar for pilot/driver selection, i.e. for activating the simulation system, or for automatic safety disengagement of the simulation. When the switch is set at the position for training mode operation illustrated in figure 1, the system is activated and the pilot/driver can use the method according to the invention. This means that at least one of the vehicle operating commands 01 is used for creating at least one vehicle command signal 10 to be used by the control system. However, if the switch is moved to another position for normal mode operation, the simulator system is disconnected and the vehicle operating commands are treated by the control system in the ordinary manner.

To create the vehicle command signals 10 a simulation means 00 is used for transformation of the vehicle operating commands 01 into the vehicle command signals 10. The simulation means comprises a calculation unit 09 for calculating vehicle command signals 10. In its simplest form the calculation unit 09 may comprise a means for receiving the vehicle operating commands 01, a pre-calculated table or similar for converting the vehicle operating commands 01 to vehicle command signals 10, and a means for emitting the vehicle command signals 10 to the vehicle 12. The vehicle command signals 10 are then used for controlling the vehicle so as to cause the vehicle 12 to respond to the vehicle operating commands 01 in a way that corresponds to the utilitarian state of the vehicle simulated by the simulation means 00 instead of the actual state of the vehicle.

In more advanced applications the simulation means 00 may comprise a load database 04, a vehicle model 07 and a more advanced calculation unit 09. The load database 04 contains data for all vehicle loads, the current configuration for the vehicle and how the loads affect the vehicle. The vehicle model 07 predicts the motion of the vehicle based on loads and operating commands. The calculation unit 09 converts the calculated

motion of the simulated vehicle 08 into vehicle command signals 10 so that the vehicle 12 follows the motion of the simulated vehicle. The calculation unit 09 can be a controller that makes the measured motion of the actual vehicle the same as the simulated vehicle. If measurements of the vehicle motion are not available or if better confidence in measurements is needed, the calculation unit 09 can also use an actual vehicle model to generate the motion of the actual vehicle. In another implementation, the calculation unit 09 can comprise an inverse actual vehicle model i.e. a model with the calculated motion of the simulated vehicle 08 as input and the vehicle command signals 10 as output.

10

A load selection unit 02 may contain data for load configuration 03 for the vehicle to be simulated and for the actual vehicle. The load data base 04 provides key data 05 for the simulated vehicle as input to the vehicle model 07, and provides key data 06 for the actual vehicle as input to the calculation unit 09.

15

The term "key data" may comprise the mass, position of the centre of gravity and the moments of inertia and the aerodynamic properties of the vehicle. The aerodynamic properties are given by the functions of the vehicle's speed, angle of attack and sideslip and angular velocities yielding the aerodynamic forces and torques.

20

The vehicle model 07 uses the key data 05 and the vehicle operating commands 01 for calculating the motion of the simulated vehicle 08. In addition, vehicle response 13 can be used in the vehicle model 07. The calculating unit 09 calculates the vehicle command signals 10 by using the calculated motion 08 of the simulated vehicle and the key data 06 for the actual vehicle as input. In addition, the vehicle operating commands 01 and/or the vehicle response 13 can be used as input to the calculation unit 09 for calculation of the vehicle command signals 10.

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By using the vehicle command signals 10 to control the vehicle 12, the vehicle responds to the propulsion provided by the propulsion system and/or the settings of the control surfaces to behave like the simulated vehicle 08. The resulting motion of the vehicle 12 is used as feedback to the system and results in the data for the vehicle response 13 changing continuously during the training.

30

With reference to figure 2 the invention is exemplified when applied in an aircraft load simulator system for training pilots to perform various kinds of missions and to deal with various kinds of situations by flying the actual aircraft in one configuration, normally being the unloaded basic configuration.

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Figure 2 illustrates an aircraft load simulator system according to the invention. The functional blocks; a load database 04, an aircraft model 07 for the simulated aircraft and a calculation unit 09 for calculation of vehicle command signals, represent the aircraft load simulator system. The remaining blocks represent the aircraft with associated control functions, pilot commands and inputs.

In this example, it is assumed that the aircraft which is to be equipped with the aircraft load simulator system has a control system comprising a system computer, a fly-by-wire control and an engine control system, such as a full authority digital engine control system. Furthermore, it is assumed that the system computer can provide information and data to the flight and engine control computers and further enables the flight and engine control systems to communicate with each other. Although, the simulator system according to the invention is preferably partly or totally integrated in the ordinary system computer of the vehicle, the simulator system could be a separate system communicating with the system computer.

Information 03 of the load configuration of the aircraft to be simulated is transferred into the software function load database 04. Loads can be in terms of internal loads, such as passenger weight, cargo weight and distribution, and fuel quantity. Loads can also be in terms of external loads such as number, type and placement of weapons, or in terms of any other internal or external loads such as extra fuel tanks, etc.

Software functions within the load database 04 will calculate the weight, centre of gravity, moments of inertia, aerodynamic properties such as drag and aerodynamic moments and performance limitations such as maximum allowed g-loads (or the g-load envelope if applicable). These calculated data are referred to as key data for the simulated aircraft 05 in Figure 2.

The actual aircraft system computer is assumed to have the ability to identify the loads for the actual aircraft configuration to be flown during the training mission. This function provides the actual aircraft with the same information as the load database does for the simulated aircraft (this information is named key data for the actual vehicle in figure 1). In this illustrating example of the invention the actual aircraft is unloaded.

When the aircraft load simulator system has been activated for initiating a training flight, key data for the simulated aircraft 05 is calculated by the load database 04 and may be updated with respect to changes in simulated and actual loads. Such changes can be because of fuel consumption and the effect of weapons being fired. Fuel consumption during the flight is in this example calculated within the aircraft model 07.

Key data for the simulated aircraft 05 is, during the training mission, continuously transferred to a software function called aircraft model 07. The key data is used together with aircraft operating commands 01 from the pilot and aircraft motion for calculating the motion of the simulated aircraft 08 in terms of e.g. angle of climb, acceleration and rotation rates (pitch, yaw, roll) by means of the aircraft model 07. The information about the actual aircraft motion is obtained from motion measurements 21 which measure the aircraft response 13.

The motion data for the actual aircraft from the motion measurements 21 is, during the training mission, continuously transferred to a calculation unit or software function called calculation of new commands 09. The data of the motion of the simulated aircraft and data for the actual flight condition are used for calculating the vehicle command signals 10. The vehicle command signals 10 comprise the actual aircraft motion commands 10a, in terms of stick, pedals and other performance-affecting settings such as trim and flaps settings, and/or the actual engine commands 10b in terms of thrust setting. In another embodiment of the invention, the engine control 31 and engine actuators 32 loop would be modified, to improve the simulation fidelity. In addition to the vehicle command signals 10, other command signals could also be used. These command signals are not limited to the type of signals which are based on signals issued by the operator, i.e. vehicle operating commands 01. For example, the transient thrust response can be improved for a gas turbine engine if both the exhaust nozzle area and the PLA (Power Lever Angle) are used as inputs to the vehicle 12. This would make it possible to improve the simulation fidelity for some manoeuvres such as the simulation of weapons release or quick turns. New command signals require that the engine control 31 and engine actuators 32 loop is modified.

The actual aircraft motion commands are transmitted to the ordinary flight control functions, i.e. motion and stability control 22, 23, where they are used for affecting the aircraft control surfaces 24. Correspondingly, the actual engine commands are transmitted to the ordinary engine control 31 where they are used for controlling the engine actuators 32.

The aircraft thus responds to the thrust provided by the engine 31 and the settings of the aircraft control surfaces 24 to behave like the simulated aircraft. The resulting motion of the aircraft is used as feedback to the system and results in the data for the aircraft response 13 being continuously changed during the flight.

To illustrate the invention in more detail, a simplified calculation example where an aircraft initially flies at a certain constant speed and altitude, and the pilot then wishes

to accelerate as quickly as possible at the same altitude, is described. Furthermore, the pilot is training for a mission that requires a certain load configuration of the aircraft, but for economical or safety reasons or other reasons, the loads are not included during training. Thus, the training aircraft has a smaller total weight than the aircraft would
 5 have in a corresponding real situation where the loads are carried by the aircraft.

The following definitions of physical conditions related to an aircraft have been used. The motion of an aircraft is described by four basic forces, see figure 3 illustrating the forces acting on an aerial vehicle. These forces are lift L , thrust T , drag D and gravity
 10 G . The drag force is directed backwards and opposite to the velocity vector v of the aircraft. The lift force is directed perpendicular to the drag force and dependent on an attack angle α between an x-axis of the aircraft (A/C x-axis) and the velocity vector v . Gravity G is directed downwards and given by the mass m of the aircraft and the gravity constant g . The pitch attitude θ is an angle between the aircraft x-axis and a fixed
 15 horizontal x-axis.

This particular example is limited to longitudinal control of the aircraft. The primary control surface for movement in the vertical plane is the elevator and the canards are used for stability. The elevator creates a rotational momentum around the y-axis of the
 20 aircraft. The velocity of the aircraft is controlled by the engine thrust setting. Thus, in this example the relevant aircraft operating commands are the stick angle affecting the elevator angle and the power lever angle PLA affecting engine thrust T . All forces acting on the aircraft are dependent on parameters such as pressure, temperature, altitude, velocity, angle of attack, aircraft aerodynamics and loads such as remaining amount of
 25 fuel, passengers, weapons etc. All these parameters are denoted p in the equations (2) and (3) which equations are described hereinafter.

The aircraft has controls for affecting control functions of the aircraft by means of vehicle operating commands. In this case a control stick can be used for affecting a
 30 flight control surface, such as the elevator angle. A power lever can be used for affecting the engine thrust. If the power lever angle PLA is increased, the throttle of the engine is opened and this will result in different accelerations dependent on aircraft loads. In this regard, reference is made to figure 4 illustrating the acceleration and increase in velocity of a loaded and unloaded aircraft for a power lever angle step from
 35 $PLA \approx 54^\circ$ to a maximum value of 100° at the time point $t=4s$.

The continuous curve represents the unloaded training aircraft without using the simulation method according to the invention. The dotted curve represents same training aircraft if loaded. It appears from the curves that the acceleration and increase

in velocity of the unloaded aircraft are very high compared to the loaded aircraft, making such pilot training less realistic and not so efficient.

As already mentioned, according to the invention a model for simulating a certain state of the aircraft and/or the environment is provided. The simulated state is a possible real state which is different from the actual state of the aircraft and/or environment. In this example, it is desired that the acceleration of the unloaded aircraft during training becomes the same as if the aircraft actually would have been loaded. The aircraft operating commands are received from the controls; in this case the thrust power lever and the elevator angle stick, and the aircraft operating commands and key data for the desired simulated state are used as input to the aircraft model for calculating vehicle command signals.

These vehicle command signals, which are different from the signals which would be expected based on the actual aircraft operating commands if the load simulator system was not in use, are then used for controlling the aircraft so as to cause the aircraft to respond to the aircraft operating commands in a way that corresponds to the state simulated by the aircraft model instead of the actual state of the aircraft.

In this case the vehicle command signals are used for controlling an engine control function, the throttle of the engine, obtaining an engine thrust which is adapted to keep the acceleration (and velocity) the same for the unloaded training aircraft as it would have been for the loaded aircraft for the same instrument setting and pilot commands without calculation of said vehicle command signals.

Assuming that the engine thrust is aligned with the aircraft x-axis, the aircraft motion expressed in fixed x-z coordinates is described below by the following relations:

$$(1) \quad \dot{x} = v \cos(\theta - \alpha), \quad \dot{z} = v \sin(\theta - \alpha)$$

$$(2) \quad \ddot{x} = \frac{1}{m} [T(p) \cos \theta - L(p) \sin(\theta - \alpha) - D(p) \cos(\theta - \alpha)]$$

$$(3) \quad \ddot{z} = \frac{1}{m} [T(p) \sin \theta + L(p) \cos(\theta - \alpha) - D(p) \sin(\theta - \alpha) - mg]$$

$$(4) \quad PLA = PLA_0 + k \cdot \left[(\ddot{x}_{sim} - \ddot{x}) + \frac{1}{T_i} \int (\ddot{x}_{sim} - \ddot{x}) dt \right]$$

Thus, the exemplified simulation is designed to keep the acceleration (and velocity) the same for the training aircraft as it would be for a loaded aircraft. A matching of the

acceleration along the x-axis is performed in equation (4) by the use of for example a PI-controller. By the PI-controller the actual engine command PLA is calculated. T_i and k are the controller time constant and gain, respectively. PLA_0 denotes the stationary thrust demand for training and will result in the same stationary velocity as for the
 5 simulated aircraft with the actual pilot command.

Although it is not explicitly described herein how the aircraft control surfaces, such as the elevator, have been controlled so as to maintain the altitude of the training aircraft, vehicle command signals are also calculated for affecting the aircraft control surfaces as
 10 desired. Of course different algorithms are required when simulating different states of the aircraft and/or the environment to the aircraft. In many applications a six dimensional problem has to be addressed, which means that flight manoeuvres in the lateral direction would also be included.

15 Furthermore, changes in important parameters such as the angle of attack, pitch attitude, or moments of inertia have not been explicitly addressed in this description. However, these parameters have been included in the exemplified simulation illustrated in figure 5 and are represented by p in equations (2) and (3).

20 The following sequence describes how the pilot commands may be transformed by means of the system and the method according to the invention.

- a) The pilot selects the appropriate training mode for the aircraft,
- b) The moment of inertia around the y-axis of the aircraft, the aircraft mass, and
 25 the centre of gravity from the load database are used together with current values and immediate history of the measured inputs to calculate the drag, lift, gravity and momentum for the simulated aircraft through the use of an aircraft model, and
- c) The motion of the simulated aircraft can then be calculated using the equations
 30 (1), (2) and (3). The system controls the aircraft such that the actual aircraft follows the simulated aircraft trajectory. By using the pilot commands and the difference between the simulated aircraft trajectory and the actual flight condition as input, the actual aircraft motion commands and the actual engine commands can be produced as output. These vehicle command signals are then
 35 used for controlling the aircraft.

On the left in figure 5, it is shown how the real acceleration of the unloaded aircraft follows the simulated acceleration (see also dashed curve in figure 4) expected for the

simulated loaded aircraft. The aircraft is tracking the model very well, which means that its performance is very similar to the performance of the simulated loaded aircraft.

5 In the example, the pilot command is a step from $PLA \approx 54^\circ$ to the maximum PLA angle of 100° , which is shown by the dashed curve on the right in figure 5. The calculated actual engine PLA-command used during the flight, which command corresponds to the pilot command and which actually affects the engine thrust, follows the lower continuous curve and makes the aircraft response similar to the response which is expected by a loaded aircraft. This concludes the simplified example.

10

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims. For example the algorithms of the model used in the method may be varied in
15 many ways.

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CLAIMS:

1. A method of simulating an operating state of an aircraft, the method comprising:

operating the aircraft via a control system, the control system being arranged
5 to receive aircraft operating commands from a person controlling the aircraft and to create aircraft operating command signals,

selectively operating the aircraft in a normal state of operation of an actual aircraft having an actual aircraft load,

selectively operating the aircraft in a simulated state of operation, the
10 simulated state of operation being different from the normal state of operation of an actual aircraft,

wherein in a simulated state of operation the aircraft operating command signals are transformed so as to simulate operation of a simulated aircraft carrying a simulated aircraft load that is different from an actual aircraft load,

15 and wherein

a load database contains data for all aircraft loads, the current configuration for the aircraft and how the loads affect the aircraft, an aircraft model predicts the motion of the aircraft based on loads and operating commands, a calculation unit converts the calculated motion of the simulated aircraft into aircraft command
20 signals so that the aircraft follows the motion of the simulated aircraft,

the information about the actual aircraft motion is obtained from motion measurements which measure the aircraft response,

the motion data for the actual aircraft from the motion measurements is, during the training mission, continuously transferred to a calculation unit, the data
25 of the motion of the simulated aircraft and data for the actual flight condition are used for calculating the vehicle command signals,

the actual aircraft motion commands are transmitted in a way that corresponds to the state simulated to the ordinary flight control functions, where they are used for affecting the aircraft control surfaces, and the actual engine commands
30 are transmitted in a way that corresponds to the state simulated to the ordinary engine control where they are used for controlling the engine actuators.

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2. A method according to claim 1 wherein the simulated aircraft load is selected from at least one of simulated passengers, simulated fuel, simulated weaponry or simulated cargo.
- 5 3. A method according to claim 2 wherein the simulated aircraft load is arranged to change over a period of time.
4. A method according to claim 1, comprising calculating the aircraft operating command signals as a function of an actual aircraft model and the aircraft operating
10 commands that are input to the actual aircraft.
5. A method according to claim 1 or 4, comprising calculating the aircraft operating command signals as a function of at least one of key data for the simulated state of the aircraft and key data for the actual aircraft.
15
6. A method according to claim 1, calculating the aircraft operating command signals as function of a model with a calculated motion of the simulated aircraft.
7. A method according to any one of claims 1 to 6, comprising calculating the
20 aircraft operating command signals using a load database.
8. A method according to claim 7, comprising using the load database to calculate key data associated with at least one of the simulated state of the aircraft and the actual state of the aircraft.
25
9. A method according to claim 8, comprising calculating the key data for the simulated state of the aircraft by using aircraft operating commands as input to the load database.
- 30 10. A method according to claim 8 or 9, comprising calculating the key data for the actual state of the aircraft by using aircraft response as input to the load database.

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11. A method according to claim 8, 9 or 10, comprising calculating the key data for the simulated state of the aircraft and/or the key data for the actual state of the aircraft by using load configuration for simulated state and/or for actual aircraft state as input to the load database.

5

12. A method according to any one of claims 1 to 11, comprising calculating the aircraft operating command signals using an aircraft model.

13. A method according to claim 12, comprising calculating, in a first step, the motion of the aircraft in the simulated state by using the aircraft model and said aircraft operating commands as input, and then calculating, in a second step, said aircraft command signals by using the calculated motion of the aircraft in the simulated state as input to the calculation unit.

14. A method according to claim 12 or 13, comprising using the key data for the simulated state of the aircraft as input to the aircraft model.

15. A method according to claim 14, comprising transmitting the key data for the simulated state of the aircraft to the aircraft model during operation of the aircraft.

20

16. A method according to claim 13, comprising calculating said aircraft operating command signals by using the aircraft operating commands as input in the second step.

17. A method according to claim 13 or 16, comprising calculating said aircraft operating command signals by using the key data for the actual aircraft as input in the second step.

18. A method according to any one of claims 1 to 17, comprising calculating the aircraft operating command signals as a function of aircraft response.

30

19. A method according to any one of claims 1 to 18, comprising using the aircraft command signals in order to simulate transient effects on aircraft motion relating to load release.

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20. A method according to any one of claims 1 to 19, comprising using pre-calculated data for calculating the aircraft operating command signals, said pre-calculated data defining the relation between certain aircraft operating commands and the aircraft operating command signals.
21. A method according to any one of claims 1 to 20, comprising using said aircraft operating command signals for controlling at least one actuator of the aircraft.
22. A method according to claim 21, comprising using said aircraft command signals for controlling at least one actuator of an engine of the aircraft.
23. A method according to claim 22, comprising using said aircraft command signals for controlling power or thrust of the engine.
24. A method according to claim 21, comprising using said aircraft command signals for controlling at least one control surface of the aircraft.
25. A method according to claim 24, comprising using said aircraft operating command signals for controlling the position of the control surface.
26. A method according to claim 21, comprising using said aircraft operating command signals for controlling at least one wheel of the aircraft.
27. A method according to claim 26, comprising using said aircraft operating command signals for controlling at least one wheel brake actuator of the aircraft.
28. A method according to any one of claims 1 to 27, comprising providing a simulated state of the aircraft wherein the weight of the aircraft is different from the real weight of the aircraft.

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29. A method according to any one of claims 1 to 28, comprising providing a simulated state of the aircraft wherein the aircraft is loaded by a load which is different from the real load.
- 5 30. A method according to any one of claims 1 to 29, comprising switching between a training mode operation where the behaviour of the aircraft in the simulated state of the aircraft can be obtained and a normal mode operation during the same operation of the aircraft.
- 10 31. A method according to any one of claims 1 to 30, comprising switching between different simulated states of the aircraft during the same flight of the aircraft, said aircraft being an air aircraft.
32. A method according to any one of claims 1 to 31, comprising training a person
15 while operating an air aircraft which can be flown in a first configuration or in a second configuration, the first and second configurations being selectable by the operator during a flight, and using the state simulated by the simulation means for simulating a transition from the first configuration to the second configuration.
- 20 33. A training system for training a person to operate an aircraft under a simulated state of an aircraft, the training system comprising:
a control system for operating the aircraft, the control system being arranged to receive aircraft operating commands from a person for controlling the aircraft and to create aircraft operating command signals,
25 means for selectively operating the aircraft in a normal state of operation of an actual aircraft having an actual aircraft load,
means for selectively operating the aircraft in a simulated state of operation, the simulated state of operation being different from the normal state of operation of an actual aircraft,
30 wherein in a simulated state of operation the aircraft operating command signals are transformed so as to simulate operation of a simulated aircraft carrying a simulated aircraft load that is different from an actual aircraft load,
and wherein

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a load database contains data for all aircraft loads, the current configuration for the aircraft and how the loads affect the aircraft, an aircraft model predicts the motion of the aircraft based on loads and operating commands, a calculation unit converts the calculated motion of the simulated aircraft into aircraft command
5 signals so that the aircraft follows the motion of the simulated aircraft,

the information about the actual aircraft motion is obtained from motion measurements which measure the aircraft response,

the motion data for the actual aircraft from the motion measurements is, during the simulated state, continuously transferred to a calculation unit, the data of
10 the motion of the simulated aircraft and data for the actual flight condition are used for calculating the vehicle command signals,

the actual aircraft motion commands are transmitted in a way that corresponds to the state simulated to the ordinary flight control functions, where they are used for affecting the aircraft control surfaces, and the actual engine commands
15 are transmitted in a way that corresponds to the state simulated to the ordinary engine control where they are used for controlling the engine actuators.

34. The training system according to claim 33 wherein the simulated aircraft load is selected from one of simulated passengers, simulated fuel, simulated weaponry
20 or simulated cargo.

35. The training system according to claim 34 wherein the simulated load is arranged to change over a period of time.

25 36. The training system according to claim 35 wherein the means for selectively operating the aircraft in the simulated state of operation transmits the aircraft operating command signals to at least one controllable component of the aircraft for controlling at least one of the propulsion system and one or more control surfaces of the aircraft so as to cause the aircraft to respond to the aircraft operating
30 commands in a way that corresponds to operation of the aircraft in the simulated state instead of the normal state.

37. A control unit comprising a computer and a computer program stored in an internal memory of the computer, said computer program being used for instructing

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a processor to accomplish the steps according to any one of claims 1-32 when the computer program is executed in the computer.

38. A computer readable medium having a stored computer program code which
5 when executed on a computer processor of a computer causes the computer to perform the steps of the method claim in any one of claims 1 to 32.

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Simulation means (00)

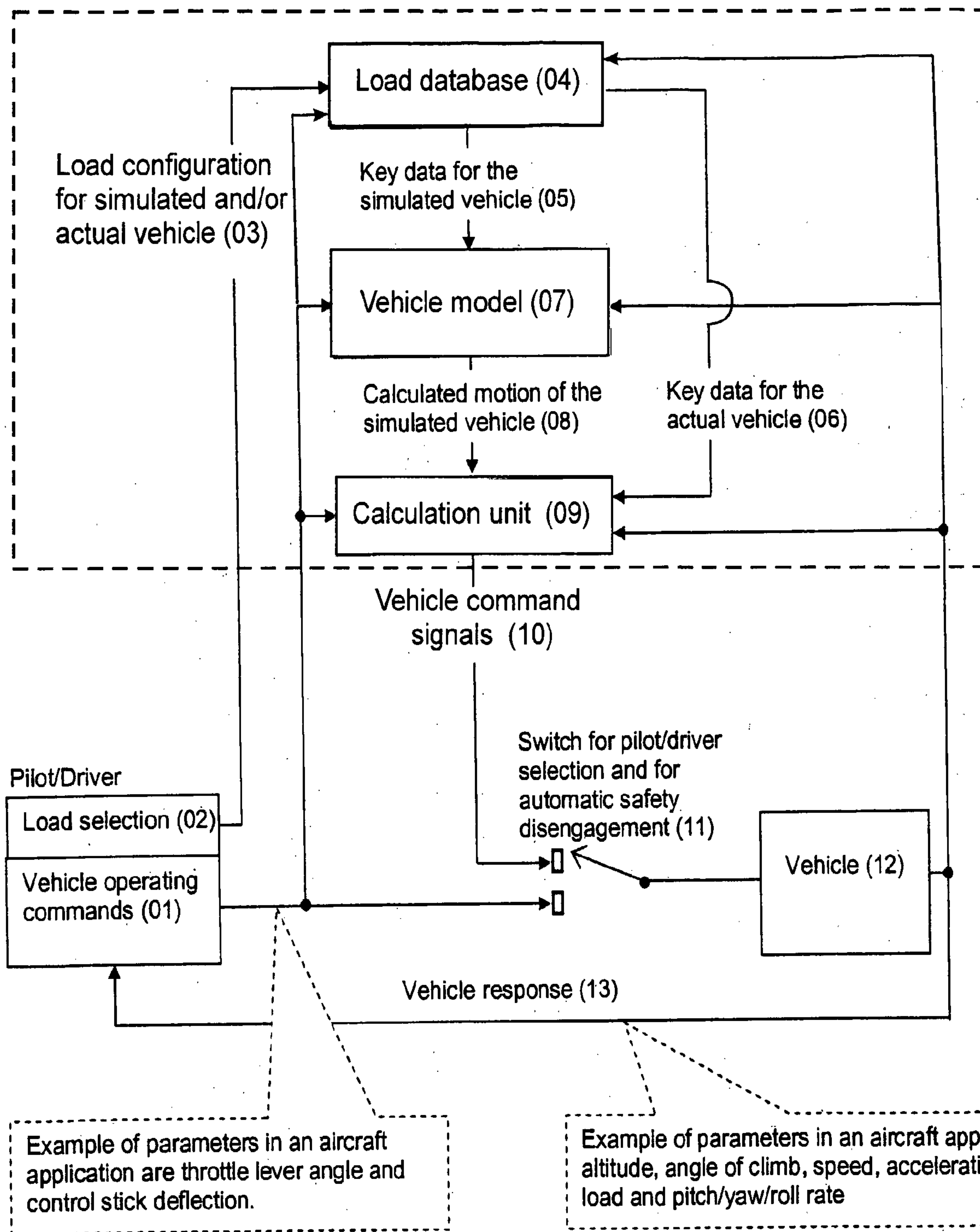


Fig. 1

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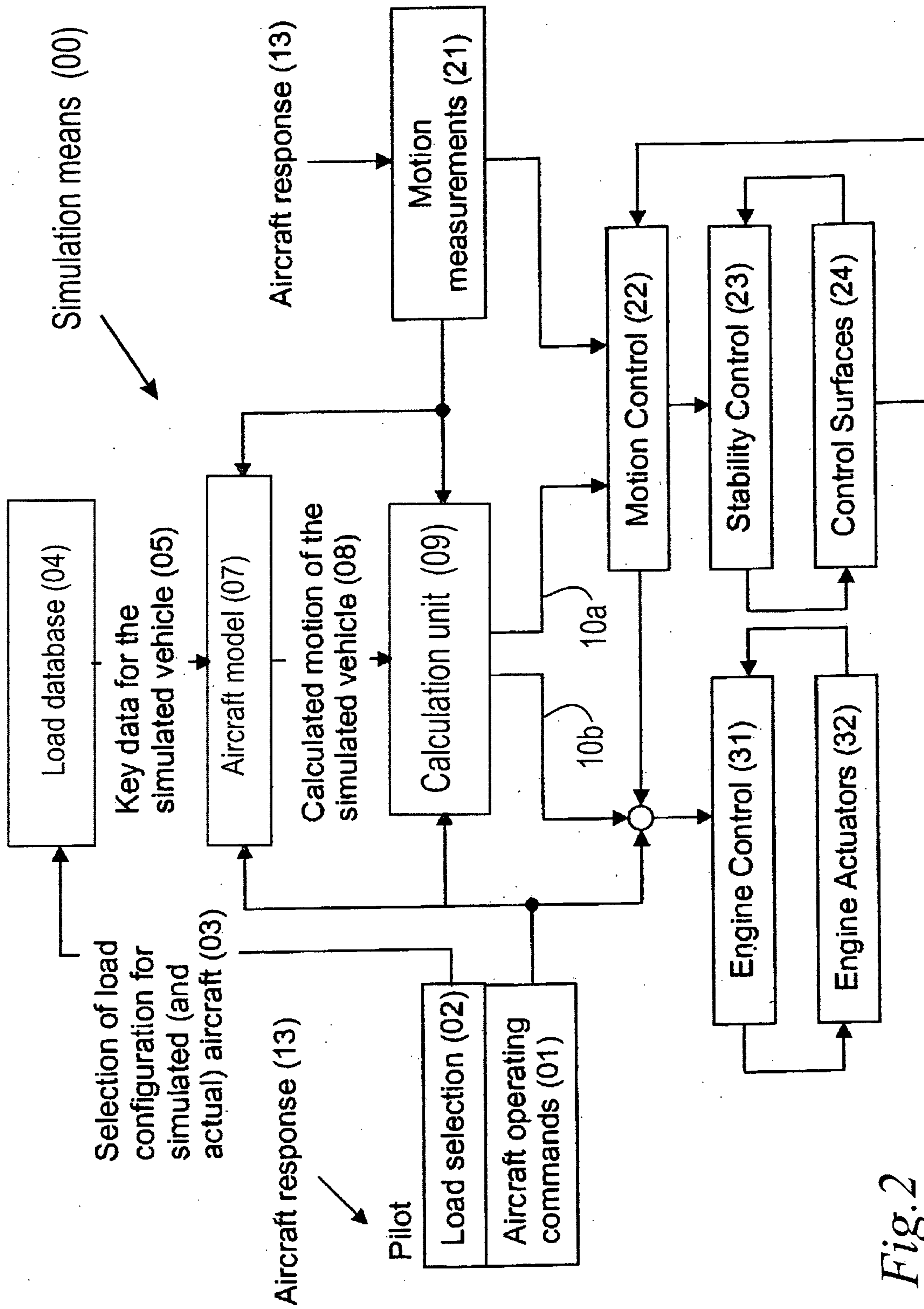
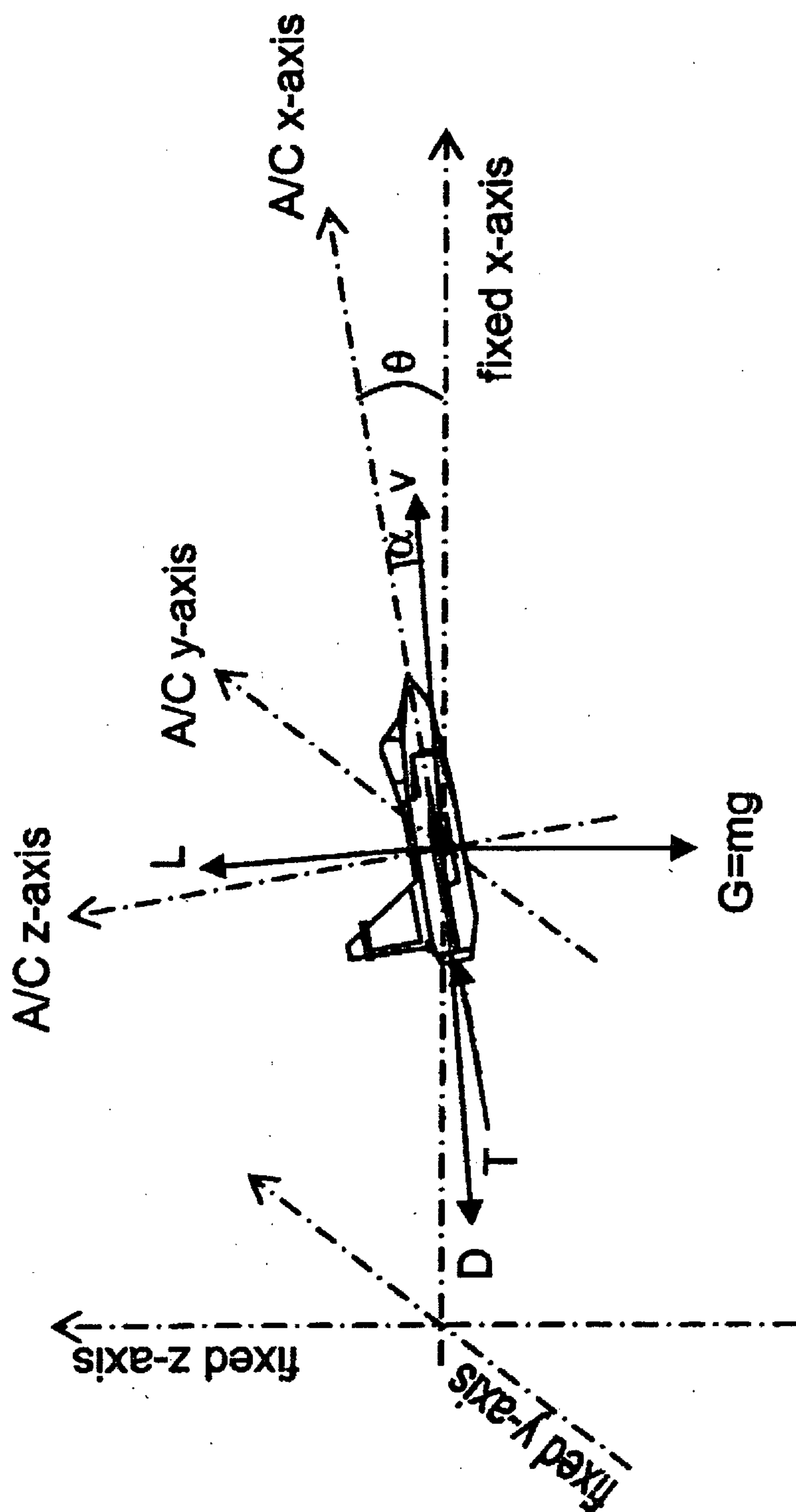
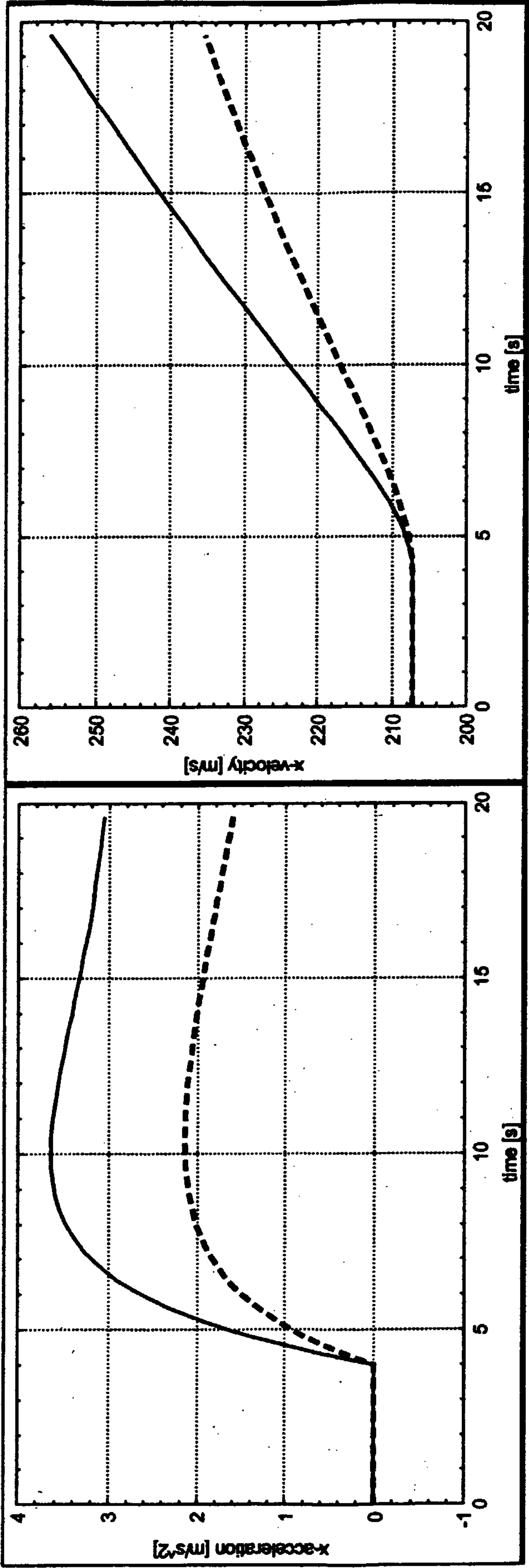


Fig. 2



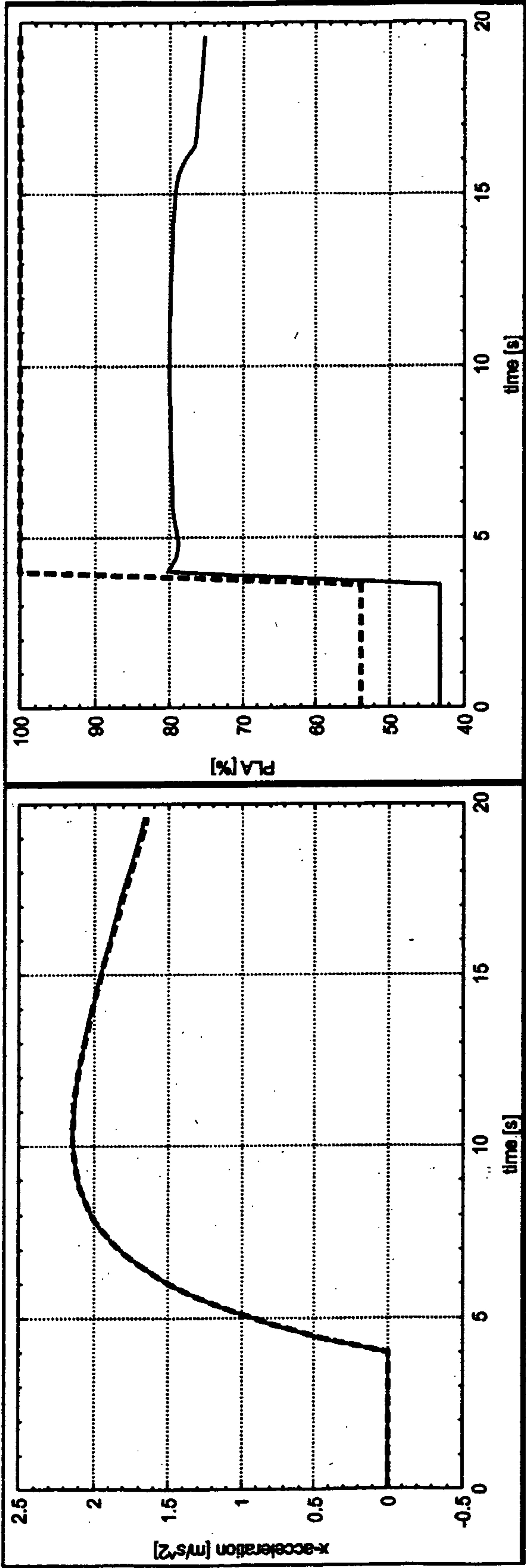
Forces acting on an aerial vehicle.

Fig.3



Maximum acceleration (left) and increase in velocity (right) of a loaded and unloaded aircraft for a PLA step at 4s.

Fig.4



Acceleration (left) and thrust command (right) for the training aircraft, dashed line for the simulated aircraft response and command.

Fig. 5

Simulation means (00)

