Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3072870 C 2023/09/12

(11)(21) **3 072 870**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date:** 2018/08/13
(87) **Date publication PCT/PCT Publication Date:** 2019/02/21
(45) **Date de délivrance/Issue Date:** 2023/09/12
(85) **Entrée phase nationale/National Entry:** 2020/02/12
(86) **N° demande PCT/PCT Application No.:** IL 2018/050896
(87) **N° publication PCT/PCT Publication No.:** 2019/035123
(30) **Priorité/Priority:** 2017/08/13 (IL253970)

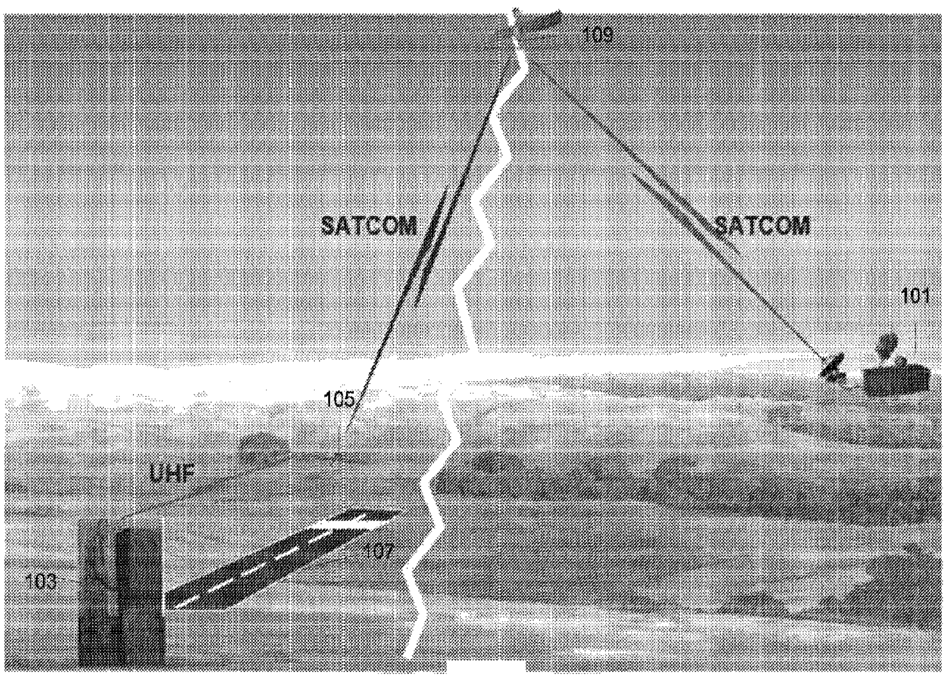
(51) **Cl.Int./Int.Cl.** ***G05D 1/00*** (2006.01)

(72) **Inventeurs/Inventors:**
REFAEL, YACOV, IL;
ZAAROUR, IDO, IL

(73) **Propriétaire/Owner:**
ISRAEL AEROSPACE INDUSTRIES LTD., IL

(74) **Agent:** OSLER, HOSKIN & HARCOURT LLP

(54) **Titre : DECOLLAGE ET ATTERRISSAGE AUTOMATIQUES PAR UN AERONEF**
(54) **Title: AUTOMATIC TAKEOFF AND LANDING BY AN AIRCRAFT**



(57) **Abrégé/Abstract:**
The presently disclosed subject matter includes an aircraft control system and an aircraft operating method which enable to control an aircraft (e.g. a UAV) by a remote aircraft control station communicating over a BLOS communication link with the aircraft, without the need to deploy an aircraft control station at a TOL site located remotely from the location of the control station. A remote takeoff and landing support (TLS) unit is deployed at the TOL site, the TLS unit comprises a DGPS which provides to the aircraft the accurate positioning data required to enable ATOL execution.

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 February 2019 (21.02.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/035123 A1

(51) International Patent Classification:
G05D 1/00 (2006.01)

(21) International Application Number:
PCT/IL2018/050896

(22) International Filing Date:
13 August 2018 (13.08.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
253970 13 August 2017 (13.08.2017) IL

(71) Applicant: **ISRAEL AEROSPACE INDUSTRIES LTD.** [IL/IL]; Ben-Gurion International Airport, 7010000 Lod (IL).

(72) Inventors: **REFAEL, Yacov**; 10 Hamelacha Street, 4744559 Ramat-HaSharon (IL). **ZAAROUR, Ido**; 178 Ben Yehuda Street, 6347116 Tel-Aviv (IL).

(74) Agent: **KRAVETZ, Yossi**; Reinhold Cohn And Partners, P.O. Box 13239, 6113102 Tel Aviv (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, 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), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) **Title:** AUTOMATIC TAKEOFF AND LANDING BY AN AIRCRAFT

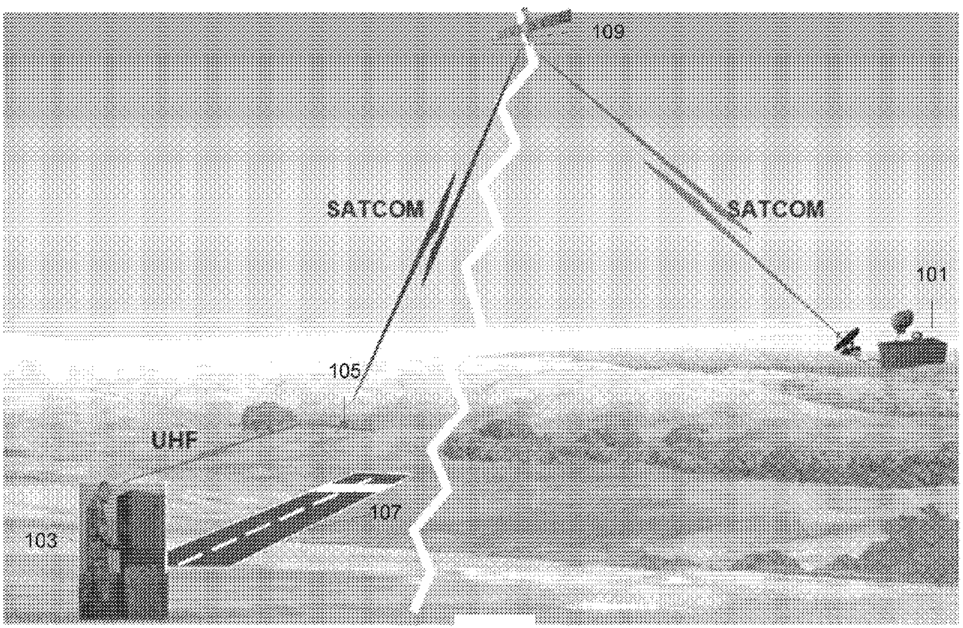


Fig. 1

(57) **Abstract:** The presently disclosed subject matter includes an aircraft control system and an aircraft operating method which enable to control an aircraft (e.g. a UAV) by a remote aircraft control station communicating over a BLOS communication link with the aircraft, without the need to deploy an aircraft control station at a TOL site located remotely from the location of the control station. A remote takeoff and landing support (TLS) unit is deployed at the TOL site, the TLS unit comprises a DGPS which provides to the aircraft the accurate positioning data required to enable ATOL execution.

WO 2019/035123 A1

[Continued on next page]

WO 2019/035123 A1

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

PCT/IL2018/050896

AUTOMATIC TAKEOFF AND LANDING BY AN AIRCRAFT

FIELD OF THE PRESENTLY DISCLOSED SUBJECT MATTER

The presently disclosed subject matter relates to the field of aircraft control and specifically to aircraft control during takeoff and landing.

BACKGROUND

Unmanned aerial vehicles (UAVs, otherwise known as remotely piloted aircraft (RPA) or remotely piloted aircraft system (RPAS)), which are predominantly used for military and special operation applications, are today becoming increasingly popular in civilian use. UAVs are used in a large variety of applications including, for example, traffic monitoring, remote sensing and reconnaissance, transportation, search and rescue, domestic policing, communication relaying, and more.

A UAV is controlled and monitored from takeoff, through flight and mission performance, and until landing. The operation of a UAV throughout its mission is controlled by an aircraft control station which is manned by an aircraft control station operator.

GENERAL DESCRIPTION

During takeoff or landing (TOL) of an aircraft accurate position data is required in order to enable safe TOL. Conventionally, an aircraft is controlled during TOL by a pilot, or in case of a UAV by a trained operator of an aircraft control station, where the aircraft and the control station maintains a line of sight (LOS) to enable the operator to guide it through the TOL process.

A UAV system normally comprises an aircraft control station (sometimes known as ground control unit (GCU)) at one location and a UAV, typically carrying some type of payload (e.g. a sensing unit such as a camera and\or RADAR), which is airborne at another location. The aircraft control station is configured to enable an operator of the aircraft control station to monitor and control the operation of a respective UAV. Control of the UAV can include both control over the operation of the UAV flight, as well as control over the operation of various payloads which may be installed on the UAV. Aircraft control station can communicate with

PCT/IL2018/050896

UAV over an LOS communication link and/or satellite based communicating link (also known as beyond line of sight (BLOS)).

In those cases where the UAV is operated at a location remote from the aircraft control station a handover process is performed before TOL. During the handover process, control over the UAV is transferred between a first aircraft control station communicating via a BLOS communication link and a second aircraft control station, located in the area of the landing/takeoff site and capable of communicating with the UAV via a LOS communication link. The handover process ensures that LOS communication, which allows more accurate control over the UAV, is available during TOL. This of course requires to maintain a fully functional aircraft control station manned by trained operators at the vicinity of the TOL area of the UAV in addition to the aircraft control station which is located remote from the UAV deployment area and is used for controlling the UAV while airborne.

The presently disclosed subject matter includes an aircraft control system and an aircraft operating method which enable to control an aircraft (e.g. a UAV) by a remote aircraft control station communicating over a BLOS communication link with the aircraft, without the need to deploy an aircraft control station at the TOL site located remotely from the aircraft control station.

As the aircraft control station is located remotely from the UAV and TOL, according to the approach suggested herein automatic takeoff or landing (ATOL) is implemented. ATOL is required in order to safely land the aircraft. Accurate positioning data, which is required for execution of the ATOL, can be obtained by a positioning system which is located within LOS communication range from the UAV. For example differential global position system (DGPS) provides positioning data sufficiently accurate for TOL. According to the presently disclosed subject matter a remote takeoff and landing support (TLS) unit is deployed at the TOL site. the TLS unit comprises a DGPS which provides to the aircraft the accurate positioning data required to enable ATOL execution.

According to one aspect of the presently disclosed subject matter there is provided a an aircraft control system enabling automatic takeoff or landing (ATOL) of an aircraft, the system comprising:

PCT/IL2018/050896

an aircraft control station configured to communicate over a beyond line of sight (BLOS) communication link with the aircraft;

a takeoff and landing support (TLS) unit, being physically separated from the aircraft control station, and configured to communicate over a line of sight (LOS) communication link with the aircraft;

an ATOL subsystem mountable on an aircraft and configured to execute automatic takeoff or landing (TOL);

the aircraft control station is configured to provide, over the BLOS communication link, navigation instructions allowing the ATOL subsystem onboard the aircraft to control the aircraft during TOL;

the TLS unit is configured to provide to the ATOL subsystem onboard the aircraft, over the LOS communication link, DGPS positioning data;

the ATOL subsystem is configured to integrate the DGPS positioning data with native position data acquired by an onboard GPS device to thereby generate augmented positioning data; and generate instructions for controlling the aircraft during TOL, based on the augmented TOL position data and the navigation instructions.

Additional to the above features, the system according to this aspect of the presently disclosed subject matter can optionally comprise one or more of features (i) to (iii) below, mutatis mutandis, in any technically possible combination or permutation.

i) The aircraft control system, wherein the TLS unit comprises an abort control device and is configured, responsive to an abort command generated responsive to interaction with the abort control device, to transmit an abort command over the LOS communication link to the aircraft; the ATOL subsystem is configured, responsive to an abort command received from the TLS unit, to abort TOR.

ii) The aircraft control system, wherein the aircraft is airborne at a remote location with respect to the location of the aircraft control station such that the range between the aircraft and the aircraft control station can communicate only by

PCT/IL2018/050896

BLOS communication.

iii) The aircraft control system, wherein the aircraft is an unmanned aerial vehicle (UAV).

According to another aspect of the presently disclosed subject matter there is provided a method of controlling an aircraft during takeoff or landing (TOL), the method comprising:

at an ATOL subsystem mounted on an aircraft, using one or more computer processors for: receiving instructions allowing the ATOL subsystem onboard the aircraft to execute ATOL process; the instructions generated at an aircraft control station located remotely from the aircraft;

receiving from a takeoff and landing support (TLS) unit being physically separated from the aircraft control station and located in close proximity of the aircraft, over a LOS communication link, DGPS positioning data;

integrating the DGPS positioning data with the native position data to thereby generate augmented positioning data; and

generating instructions for controlling the aircraft during TOL, based on the augmented TOL position data.

Additional to the above features, the method according to this aspect of the presently disclosed subject matter can optionally comprise one or more of features (i) to (iv) below, mutatis mutandis, in any technically possible combination or permutation.

i) The method further comprising, operating one or more flight control devices according to the instructions for executing TOL.

ii) The method further comprising:

at the TLS unit, using one or more computer processor for:

generating an abort command in response to user interaction with an abort control device in the TLS unit;

generating instructions to abort the TOL in response to the received abort command;

transmitting the instruction to the ATOL subsystem; and

PCT/IL2018/050896

at the ATOL subsystem:

aborting the TOL in accordance with the received TOL abort command.

iii) The method, wherein the aircraft is a UAV.

iv) The method further comprising:

receiving at the aircraft, over the BLOS communication link, flight instructions received from the aircraft control station, located remotely from the aircraft and directed for controlling the aircraft during flight.

According to another aspect of the presently disclosed subject matter there is provided a non-transitory program storage device readable by a computer, tangibly embodying a computer readable instructions executable by the computer to perform a method of controlling an aircraft during takeoff or landing (TOL), the method comprising:

at an ATOL subsystem mounted on an aircraft, receiving instructions allowing the ATOL subsystem onboard the aircraft to execute ATOL process;

receiving from a takeoff and landing support (TLS) unit being physically separated from the aircraft control station and located in close proximity of the aircraft, over a LOS communication link, DGPS positioning data;

integrating the DGPS positioning data with the native position data to thereby generate augmented positioning data; and

generating instructions for controlling the aircraft during TOL, based on the augmented TOL position data.

According to another aspect of the presently disclosed subject matter there is provided a method of controlling an aircraft during takeoff or landing (TOL), the method comprising:

at an aircraft control station located remotely from the aircraft generating and transmitting to an ATOL subsystem mounted on an aircraft, for causing the ATOL subsystem to execute ATOL process, comprising:

receiving from a takeoff and landing support (TLS) unit being physically separated from the aircraft control station and located in close proximity of the aircraft, over a LOS communication link, DGPS positioning data;

integrating the DGPS positioning data with the native position data to thereby generate augmented positioning data; and

generating instructions for controlling the aircraft during TOL, based on the augmented TOL position data.

According to another aspect of the presently disclosed subject matter there is provided a takeoff and landing support (TLS) unit for enabling takeoff or landing of an aircraft with an onboard ATOL subsystem; the TLS unit comprising:

a DGPS configured for generating DGPS positioning data and an LOS communication unit configured for communicating with the aircraft;

the TLS unit is configured to provide to the ATOL subsystem mounted onboard the aircraft, over the LOS communication link, the DGPS positioning data and thereby enable the ATOL subsystem to integrate the DGPS positioning data with native position data acquired by a GPS device onboard the aircraft to thereby generate augmented positioning data and to generate instructions for controlling the aircraft during TOL, based on the augmented TOL position data and on navigation instructions received from a remote aircraft control station.

The computer storage device and TLS unit disclosed in accordance with the presently disclosed subject matter can optionally comprise one or more of features (i) to (iv) listed above, mutatis mutandis, in any technically possible combination or permutation.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the presently disclosed subject matter and to see how it may be carried out in practice, the subject matter will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of an aircraft control system, in accordance with some examples of the presently disclosed subject matter;

PCT/IL2018/050896

Fig. 2 is a block diagram schematically illustrating an aircraft control system, in accordance with some examples of the presently disclosed subject matter;

Fig. 3 is a flowchart showing an example of operations carried out as part of an automatic landing process, in accordance with some examples of the presently disclosed subject matter;

Fig. 4 is a flowchart showing an example of operations carried out as part of an automatic takeoff process, in accordance with some examples of the presently disclosed subject matter

DETAILED DESCRIPTION

Elements in the drawings are not necessarily drawn to scale. Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "receiving", "transmitting", "generating", "integrating", "executing" or the like, include actions and/or processes of a computer that manipulate and/or transform data into other data, said data represented as physical quantities, e.g. such as electronic quantities, and/or said data representing the physical objects.

Units **101**, **103** and onboard ATOL subsystem described below, comprise or are otherwise operatively connected to one or more computer devices. The terms "computer", "computer device", "computerized device", "computer system", or variation thereof should be expansively construed to include any kind of electronic device with a processing circuitry capable of data processing and which includes one or more computer processors operatively connected to a computer memory (optionally including non-transitory computer memory) operating together for executing and/or generating instructions. Examples of such a device include: digital signal processor (DSP), a microcontroller, a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), a personal computer, server computer device, a dedicated processing device, etc.

As used herein, the phrase "for example," "such as", "for instance" and variants thereof describe non-limiting embodiments of the presently disclosed subject matter. Reference in the specification to "one case", "some cases", "other cases" or variants thereof means that a

PCT/IL2018/050896

particular feature, structure or characteristic described in connection with the embodiment(s) is included in at least one embodiment of the presently disclosed subject matter. Thus the appearance of the phrase "one case", "some cases", "other cases" or variants thereof does not necessarily refer to the same embodiment(s).

It is appreciated that certain features of the presently disclosed subject matter, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the presently disclosed subject matter, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

In embodiments of the presently disclosed subject matter, fewer, more and/or different stages than those shown in Figs. **3** and **4** may be executed. Also the order of execution of the described operations should not be limited to the order which is presented in the figures.

Figs. **2** is a schematic illustration of a system in accordance with some examples of the presently disclosed subject matter. Components in Fig. **2** may be centralized in one location or dispersed over more than one location. In other embodiments of the presently disclosed subject matter, the system may comprise fewer, more, and/or different modules than those shown in Fig. **2**.

Bearing the above in mind, attention is now drawn to Fig. **1** showing a schematic illustration of an operative aircraft control system **100**, according to some examples of the presently disclosed subject matter. Fig. **1** shows a deployed aircraft control system comprising an aircraft control station **101**, a takeoff and landing support unit **103** and an aircraft **105** (e.g. UAV). Aircraft **105** is operating at an area which is remote from the location of deployment of the aircraft control station **101**. More specifically, a takeoff and landing runway (TLR) **107** is located remotely from the aircraft control station **101** and therefore communication between aircraft **105** and aircraft control station **101** is possible by BLOS communication only.

The term "remote" or any variation therefore is used herein to describe relative position of two communicating systems suitable only for beyond line of sight (BLOS) communication. This can be either due to the range between the two elements or due to

PCT/IL2018/050896

objects, land cover or topography that obstructs line of sight communication. Thus, two communication devices which are located at remote locations, one with respect to the other, can communicate only by a BLOS communication link. Fig. **1** shows that satellite communication (SATCOM), via satellite **109**, is used for communicating between the aircraft control station **101** and the aircraft **105**.

The term "close proximity" is used herein to describe a relative position of two communicating systems suitable for LOS communication. In Fig. **1**, different than aircraft control station **101**, TLS unit **103** is located in close proximity to the TLR **107** and therefore can communicate with the aircraft over a line of sight (LOS) communication link (using for example Ultra High Frequency (UHF) radio communication) during takeoff or landing of the aircraft.

Fig. **2** is a block diagram schematically illustrating aircraft control system, in accordance with some none limiting examples of the presently disclosed subject matter. As mentioned above, aircraft control system **100** comprises aircraft control station **101**, TLS unit **103** and an automatic takeoff and landing subsystem, which is mountable on an aircraft **105**. As apparent from Fig. **1** above, TLS unit **103** is physically separated from control station **101** where TLS is located in closed proximity to TLR **107** and control station **101** is located remotely from TLR **107**.

According to some examples, aircraft control station **101** comprises pilot box (PBX) comprising an operator console and configured to enable interaction with a ground aircraft control station (GCS) and control an aircraft (e.g. UAV). GCS can comprise for example, ATOL control system configured to execute and monitor automatic takeoff or landing, and DGPS configured to calculate and provide accurate positioning data errors, as known in the art.

GCS is further connected to ground data terminal (GDT) and ground satellite equipment (GSAT). GDT is configured to communicate (e.g. with an aircraft) over line of sight communication link (e.g. UHF transmitter and controller (UTC)) and GSAT is configured to communicate with the aircraft over satellite based (BLOS) communication link.

Notably , according to some examples the architecture of aircraft control station **101** can be designed in compliance with the requirements of STANAG 4586 which is the NATO specification of a core UAV control system (CUCS), however this is not always necessary.

TLS unit **103** comprises only a selected part of the functionalities of aircraft control station **101** and accordingly its dimensions and weight are significantly smaller than those of aircraft control station **101**. For example, TLS unit **103** may not comprise GSAT and is accordingly incapable of BLOS communication with the aircraft. Different than aircraft control station **101**, TLS unit **103** may be designed not to have full control over the flight of the aircraft (and possibly neither to have control over various payloads onboard the aircraft). In some examples TLS unit **103** is configured to have limited control over specific operations of the aircraft during TOL. Thus, unlike an aircraft control station **101**, operation of a TLS unit **103** does not require extensive training of operators.

TLS unit **103** comprises a computer device operatively connected to a DGPS and an LOS communication unit (e.g. UTC). This allows TLS **103** to calculate and transmit to an aircraft, over a LOS communication link, DGPS positioning data to thereby enable accurate positioning of the aircraft, during TOL. The computerized device can further comprise or be otherwise operatively connected to a PBX to enable user interaction with the TLS unit.

According to some examples TLS unit **103** further comprises an abort control device (which can be for example, any one of: a graphical user interface button displayed over a computer screen of TLS unit computer, physical abort button, key or lever, etc.) configured to allow an operator to issue an abort command for aborting TOL. Since TOL takes place at a remote area an abort input device is provided at the TLS unit to allow cancellation of the TOL process by a technician or flight supervisor operating the TLS unit who is located near the TOL site and has a line of sight with the aircraft, and to thereby increase TOL safety. for example, if the flight supervisor identifies that there is another aircraft on the runway, an abort command cancelling the landing or takeoff process can be issued to avoid dire consequences.

Aircraft **105** comprises a flight control subsystem, the flight control subsystem is configured to control the aircraft during ATOL and while airborne. Flight control subsystem, can be configured, responsive to flight instructions received over a BLOS communication link from aircraft control station **101**, to control the aircraft. Flight control subsystem can be operatively connected to various onboard flight control subsystems (including for example, rudder control unit, ailerons control unit, flap control unit, throttle control unit, etc.) and generate commands for controlling these subsystems according to the received instructions.

PCT/IL2018/050896

ATOL subsystem is mountable on aircraft **105** and configured to execute automatic takeoff or landing. In some examples, onboard ATOL subsystem can be operatively connected to flight control subsystem to facilitate control the aircraft during TOL. Activation of ATOL can be in response to received ATOL activation command, transmitted for example over a BLOS communication link from aircraft control station **101**. As explained further below onboard ATOL subsystem is configured to execute an ATOL process where DGPS data is received over a LOS communication link from TLS unit **103** and navigation instructions are received by BLOS communication link from aircraft control station **101**. The received DGPS data is integrated with native positioning data, determined by an onboard GPS subsystem to thereby obtain positioning data with augmented accuracy. Autonomous control over the aircraft during execution of ATOL is done according to navigation instructions and the augmented positioning data. This allows to perform TOL of the aircraft from a runway located remotely from the aircraft control station **101**.

Notably, an inherent delay in BLOS communication creates a time gap between the time when sensing data (e.g. images) is obtained by the aircraft at the landing site and a time the sensing data is received at the aircraft control station and a further time when a command for controlling the aircraft responsive to the sensing data, generated at the aircraft control station, is received and executed at the aircraft. Due to this inherent time delay in BLOS communication and the need for accurate control over the aircraft during TOL, TOL cannot be controlled from a remote aircraft control station even if the positioning data provided by the station is sufficiently accurate. Rather, as disclosed herein, ATOL is implemented instead.

Example of techniques for implementing ATOL are provided by way of example, in publication entitled "Advanced flight control technologies for UAVs" by Moshe Attar, Elias Wahonon and Doron Chaimovitz; Israeli Aircraft Industries – Engineering Division; 2end AIAA "Unmanned Unlimited" Systems, Technologies, and Operations –Aerospac 15-18 September 2003, San Diego, Californian.

Fig. **3** is a flowchart showing a sequence of operations carried out as part of automatic landing process, according to an example of the presently disclosed subject matter. Operations described with reference to Fig. **3** (as well as Fig. **4** below) can be executed by components of aircraft control system **100** described above. However, it is noted that reference made to

PCT/IL2018/050896

specific components illustrated in Fig. **1** is made by way of example only and should not be construed as limiting.

At block **301** an airborne aircraft **105** is controlled by a remote aircraft control station **101**. As mentioned above due to the remoteness between the aircraft and the aircraft control station, communication between the two is facilitate by a BLOS communication link. In some examples, initial takeoff of the aircraft can be executed by the aircraft control station **101** from a runway located in close proximity to the aircraft control station **101**. Once airborne, the aircraft can be directed to fly to an area, where communication between aircraft and aircraft control station is only possible by a BLOS communication link.

At block **303** a TLS unit is deployed in the vicinity (close proximity) of the anticipated landing site, e.g. a takeoff and landing runway (TLR **107**) located remotely from the aircraft control station **101**. TLS unit can be deployed for example by small team of technicians (e.g. between 1 to 3 technicians). In to some examples, TLS unit is activated once the aircraft reaches an area close to the runway, e.g. once the aircraft is within LOS communication range. In some examples, operation of the TLS unit and/or communication between the aircraft and the TLS unit is initiated in response to a command transmitted from the aircraft control station **101**.

The aircraft can be controlled from the aircraft control station **101** until it reaches the remote runway. Before TOL onboard ATOL subsystem is activated (Block **305**). Activation of ATOL subsystem can be for example in response to an activation command received over BLOS communication from aircraft control station **101**.

At block **307** DGPS positioning data is calculated by a DGPS operatively connected to the TLS and transmitted to the aircraft using the LOS communication link. Transmitted DGPS positioning data is received for examples at onboard ATOL subsystem.

At block **309** TOL control instructions are transmitted from the aircraft control station **101** (over BLOS communication) to the aircraft. TOL control instructions can include for example, navigation instructions. Navigation instruction includes for example, coordinates of touchdown point on runway and of waypoints of predetermined landing approach path including and the like. TOL control instructions can also include a TOL activation command.

PCT/IL2018/050896

ATOL subsystem initiates the landing process, where the navigation data is used for controlling the aircraft along the approach path for landing. During autonomous navigation of the aircraft for landing, DGPS data is integrated with native GPS data (e.g. data determined by a GPS subsystem onboard the aircraft) and GPS data with augmented accuracy is generated based on the DGPS data (block **311**). The augmented GPS data is used for controlling the aircraft along the landing approach path and during actual landing of the aircraft on the runway (block **313**).

According to some examples if it is desired to abort the landing of the aircraft, an operator of the TLS unit can interact with the abort control device (e.g. press an abort button, or pull an abort lever) to thereby issue a landing abort command which is transmitted automatically to the aircraft. Responsive to the landing abort command the aircraft ceases the landing process e.g. can rise back to circle around the landing site. Examples of abort situations include an un-cleared runway, an un-cleared landing approach path, dangerous landing conditions e.g. bad weather, etc.

Fig. **4** is a flowchart showing a sequence of operations carried out as part of automatic takeoff process, according to an example of the presently disclosed subject matter.

At block **401** an aircraft **105** is prepared for takeoff from a runway. Preparation include for example positioning the aircraft on the runway in a ready to takeoff position and performing various pre-flight checks. At block **403** the control over the aircraft is given to an aircraft control station **101** located remotely from the runway, which can communicate with the aircraft over a BLOS communication link. At block **405** TOL control instructions are provided by the aircraft control station **101** to the aircraft from aircraft control station **101** over BLOS communication link. TOL control instructions can include for example, ATOL activation command for activating the onboard ATOL subsystem, TOL initiation command for initiating TOL and navigation instructions. Navigation instructions include for example, way points coordinates of takeoff route and of flight route for flying following takeoff.

At block **407** DGPS positioning data is calculated at the TLS unit and transmitted to the aircraft. Transmitted DGPS positioning data can be received for examples by onboard ATOL subsystem.

PCT/IL2018/050896

Following activation ATOL subsystem initiates a takeoff process, where the navigation data is used for controlling the aircraft during takeoff. During autonomous navigation of the aircraft, DGPS data is integrated with native GPS data (e.g. determined by a GPS subsystem onboard the aircraft) and GPS data with augment accuracy is generated based on the DGPS data (block **409**). The augmented GPS data is used for controlling the aircraft along the takeoff process and also later along the initial stages of the aircraft flight route (block **411**).

According to some examples if it is desired to abort the takeoff of the aircraft, the operator of the TLS unit can interact with the abort control device (e.g. press an abort button) to thereby issue a takeoff abort command which is transmitted automatically to the aircraft. Responsive to the takeoff abort command the aircraft ceases the takeoff process e.g. can stop on the runway before takeoff.

The presently disclosed subject matter enables to execute safe takeoff or landing of an aircraft at a TOL site located remotely from an aircraft control station. This approach helps to reduce costs and to simplify operation of the aircraft control station **100** as it does not require to deploy a fully functional aircraft control station at the TOL site and also does not require to accommodate trained aircraft control station operators at the TOL site. For example, a UAV aircraft control station can be located thousands of kilometers away from the operation area of the UAV and be used for controlling the UAV while airborne. During TOL, onboard ATOL subsystem is activated and controls the UAV while communicating with TLS unit for obtaining DGPS data needed for calculating accurate position data. Additional application of the disclosed system and method include for example: transferring aircrafts by flying rather than as cargo, to any destination lacking an aircraft control station and/or trained operators of an aircraft control station; training operators of aircraft control stations, where the aircraft control stations are located remotely from the TOL site of the aircrafts.

The embodiments of the present invention for which an exclusive property or privilege is claimed are defined as follows:

1. An aircraft control system enabling automatic takeoff or landing (ATOL) of an aircraft, the system comprising:

an aircraft control station configured to communicate over a beyond line of sight (BLOS) communication link with the aircraft for controlling the aircraft while airborne;

a takeoff and landing support (TLS) unit, deployable near a TOL site being physically separated from the aircraft control station, and configured to communicate over a line of sight (LOS) communication link with the aircraft;

an ATOL subsystem mountable on the aircraft and configured to execute automatic takeoff or landing (TOL);

wherein during takeoff or landing:

the aircraft control station is configured to provide, over the BLOS communication link, navigation instructions allowing the ATOL subsystem onboard the aircraft to control the aircraft during TOL;

the TLS unit is configured to provide to the ATOL subsystem onboard the aircraft, over the LOS communication link, DGPS positioning data;

the ATOL subsystem is configured to integrate the DGPS positioning data with native position data acquired by an onboard GPS device to thereby generate augmented TOL positioning data; and generate instructions for controlling the aircraft during TOL, based on the augmented TOL position data and the navigation instructions.

2. The aircraft control system of claim 1, wherein the TLS unit comprises an abort control device and is configured, responsive to an abort command generated responsive to interaction with the abort control device, to transmit an abort command over the LOS communication link to the aircraft; the ATOL subsystem is configured, responsive to an abort command received from the TLS unit, to abort TOR.

Date Reçue/Date Received 2022-06-09

3. The aircraft control system of claim 1 or 2, wherein the aircraft is airborne at a remote location with respect to the location of the aircraft control station such that communication between the aircraft and the aircraft control station is possible only by BLOS communication.

4. The aircraft control system of any one of claims 1 to 3, wherein the aircraft is an unmanned aerial vehicle (UAV).

5. The aircraft control system of any one of claims 1 to 4, wherein the aircraft control station is configured to transmit to the ATOL subsystem, ATOL initiation instructions.

6. A method of controlling an aircraft during takeoff or landing (TOL), the method comprising:

at an ATOL subsystem mounted on the aircraft, using one or more computer processors for:

receiving, over a beyond line of sight (BLOS) communication link used for communicating with an aircraft control station located remotely from the aircraft, flight instructions generated at the aircraft control station directed for controlling the aircraft during flight;

receiving over a BLOS communication link instructions allowing the ATOL subsystem onboard the aircraft to execute an ATOL process; the instructions are generated at the aircraft control station;

receiving from a takeoff and landing support (TLS) unit, deployable near a TOL site, being physically separated from the aircraft control station and located in close proximity of the aircraft, over a LOS communication link, DGPS positioning data;

integrating the DGPS positioning data with native position data to thereby generate augmented positioning data; and

generating TOL instructions for controlling the aircraft during TOL, based on the augmented TOL position data.

7. The method of claim 6 further comprising, operating one or more flight control devices according to the TOL instructions.

8. The method of claim 6 or 7 further comprising:

at the TLS unit, using one or more computer processor for:

generating an abort command in response to user interaction with an abort control device in the TLS unit;

generating instructions to abort the TOL in response to the received abort command;

transmitting the instruction to the ATOL subsystem; and

at the ATOL subsystem:

aborting the TOL in accordance with the received TOL abort command.

9. The method of any one of claims 6 to 8, wherein the aircraft is a UAV.

10. The method of any one of claims 6 to 9, wherein the instructions include navigation instruction for controlling the aircraft during TOL; the TOL instructions are generated also based on the navigation instructions.

11. The method according to any one of claims 6 to 8, wherein communication between the aircraft and the aircraft control station is possible only by a BLOS communication link.

12. A non-transitory program storage device readable by a computer, tangibly embodying a computer readable instructions executable by the computer to perform a method of controlling an aircraft during takeoff or landing (TOL), the method comprising:

operating one or more computer processors of an ATOL subsystem mounted on an aircraft;

receiving, over a beyond line of sight (BLOS) communication link used for communicating with an aircraft control station located remotely from the aircraft, flight instructions generated at the aircraft control station directed for controlling the aircraft during flight;

receiving over a BLOS communication link instructions allowing the ATOL subsystem onboard the aircraft to execute an ATOL process; the instructions are generated at the aircraft control station;

receiving from a takeoff and landing support (TLS) unit being physically separated from the aircraft control station deployable near a TOL site and located in close proximity of the aircraft, over a LOS communication link, DGPS positioning data;

integrating the DGPS positioning data with native positioning data to thereby generate augmented positioning data; and

generating TOL instructions for controlling the aircraft during TOL, based on the augmented positioning data and the instructions generated at the aircraft control station.

13. A non-transitory program storage device readable by a computer, tangibly embodying a computer readable instructions executable by the computer to perform a method of controlling an aircraft during takeoff or landing (TOL), the method comprising:

an aircraft control station configured to communicate over a beyond line of sight (BLOS) communication link with the aircraft for controlling the aircraft while airborne;

a takeoff and landing support (TLS) unit, deployable near a TOL site being physically separated from the aircraft control station, and configured to communicate over a line of sight (LOS) communication link with the aircraft;

an ATOL subsystem mountable on an aircraft and configured to execute automatic takeoff or landing (TOL);

the aircraft control station is configured to provide, over the BLOS communication link, instructions allowing the ATOL subsystem onboard the aircraft to control the aircraft during TOL;

the TLS unit is configured to provide to the ATOL subsystem onboard the aircraft, over the LOS communication link, DGPS positioning data;

Date Reçue/Date Received 2022-06-09

the ATOL subsystem is configured, responsive to an activation command to:

integrate the DGPS positioning data with native position data acquired by an onboard GPS device to thereby generate augmented TOL positioning data; and

generate instructions for controlling the aircraft during TOL, based on the augmented TOL position data.

14. An aircraft control system enabling automatic takeoff or landing (ATOL) of an aircraft, the system comprising:

a takeoff and landing support (TLS) unit, deployable near a TOL site, being physically separated from an aircraft control station, and configured to communicate over a line of sight (LOS) communication link with the aircraft; wherein communication between the aircraft control station and the aircraft includes a beyond line of site (BLOS) communication link, which is used for controlling the aircraft while airborne;

an ATOL subsystem mountable on an aircraft and configured to execute automatic takeoff or landing (TOL);

the ATOL subsystem, onboard the aircraft is configured to receive from the aircraft control station, over the BLOS communicating link, navigation instructions, allowing the ATOL subsystem to control the aircraft during TOL;

the TLS unit is configured to provide to the ATOL subsystem onboard the aircraft, over the LOS communication link, DGPS positioning data;

the ATOL subsystem is configured to integrate the DGPS positioning data with native positioning data acquired by an onboard GPS device to thereby generate augmented positioning data; and generate instructions for controlling the aircraft during TOL, based on the augmented position data and the navigation instructions.

15. The aircraft control system of claim 14, wherein the TLS unit comprises an abort control device and is configured, responsive to an abort command generated responsive to interaction with the abort control device, to transmit an abort command over

the LOS communication link to the aircraft; the ATOL subsystem is configured, responsive to an abort command received from the TLS unit, to abort TOL.

16. The aircraft control system of claim 14 or claim 15 comprising the aircraft control station, wherein the aircraft is airborne at a remote location with respect to the location of the aircraft control station such that communication between the aircraft and the aircraft control station is possible only by BLOS communication.

17. The aircraft control system of any one of claims 14 to 16, wherein the aircraft is an unmanned aerial vehicle (UAV).

18. The aircraft control system of any one of claims 14 to 17 comprising the aircraft control station, wherein the aircraft control station is configured to transmit ATOL initiation instructions to the ATOL subsystem over the BLOS communication link.

PCT/IL2018/050896

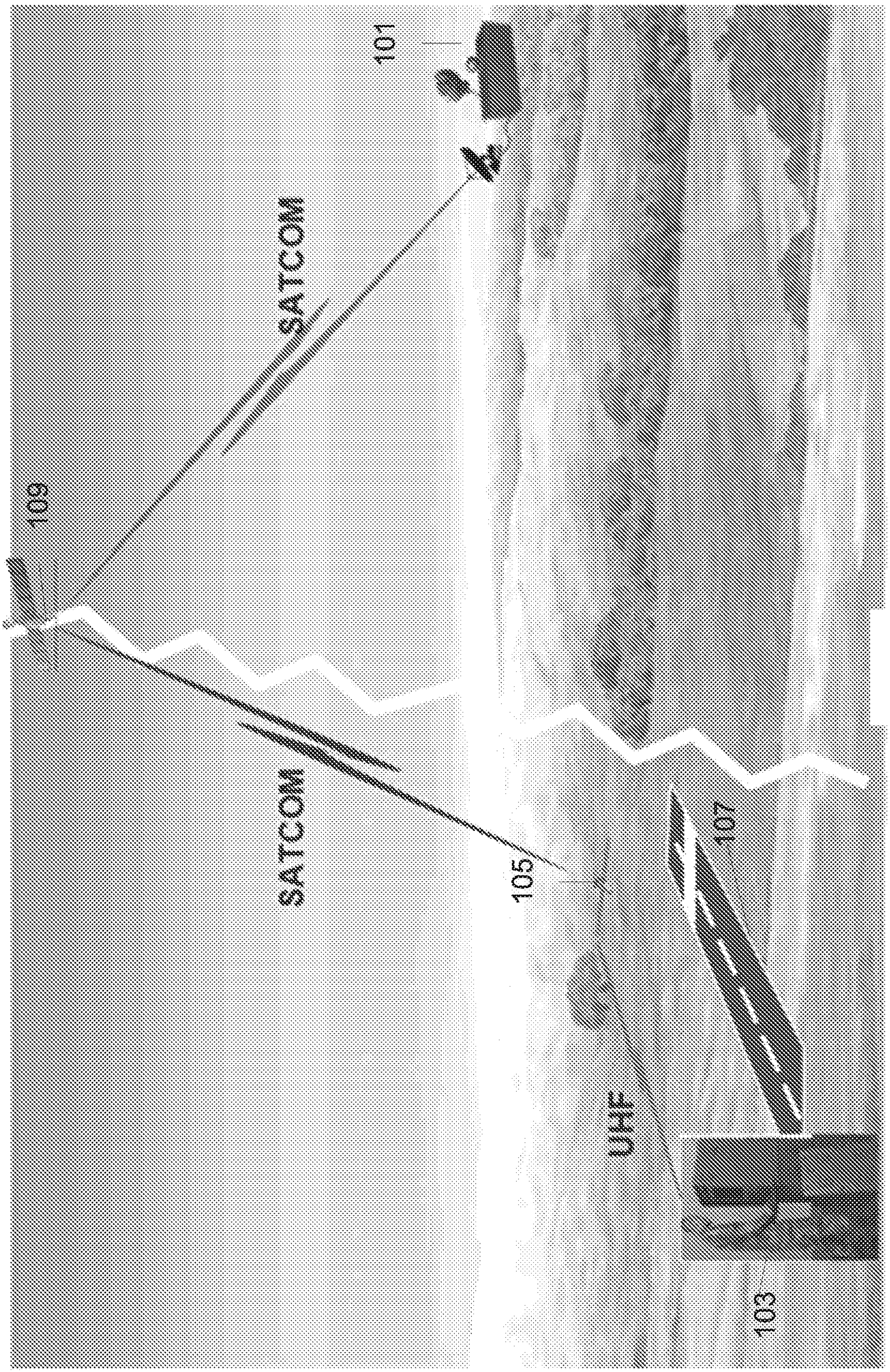


Fig. 1

PCT/IL2018/050896

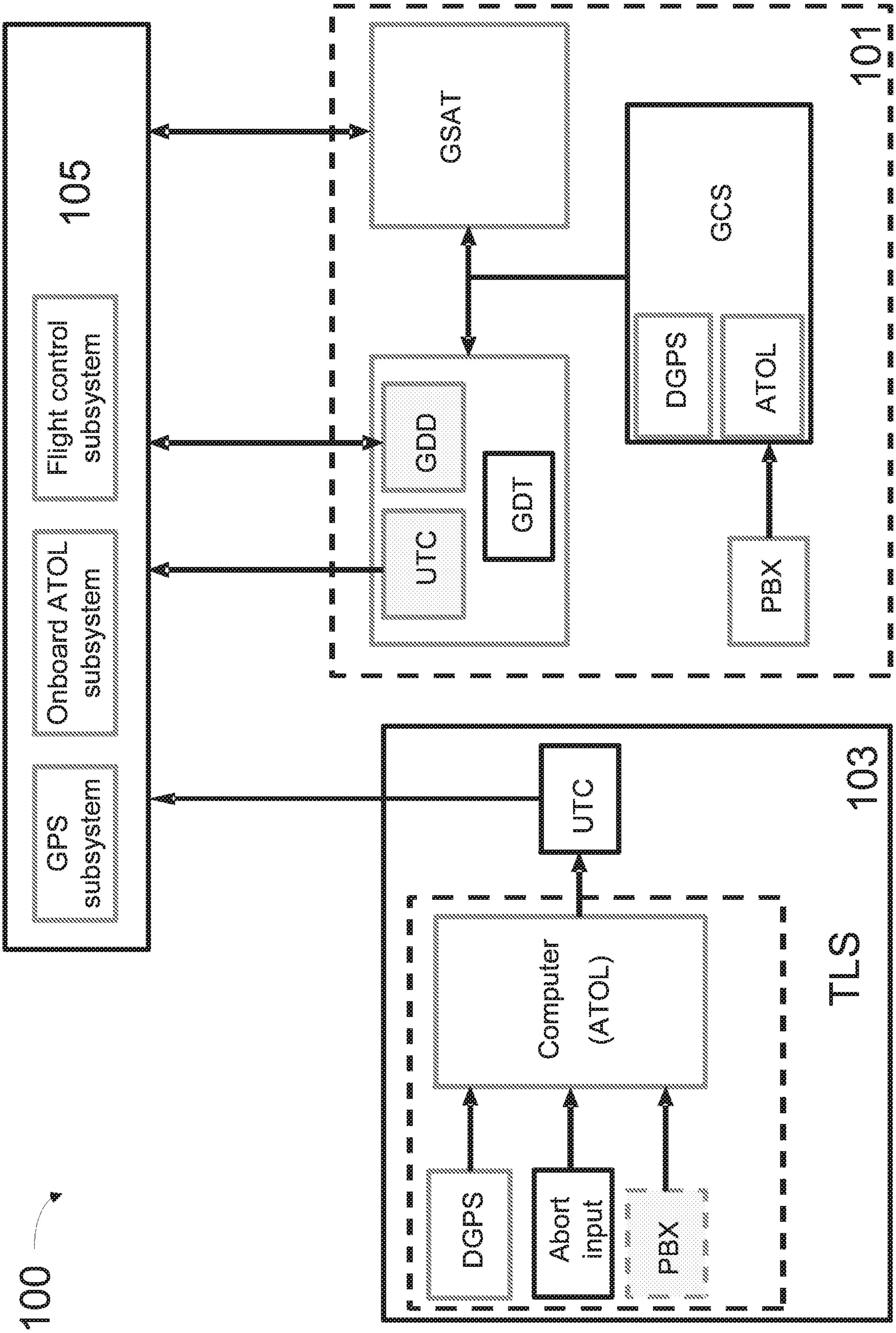


Fig. 2

PCT/IL2018/050896

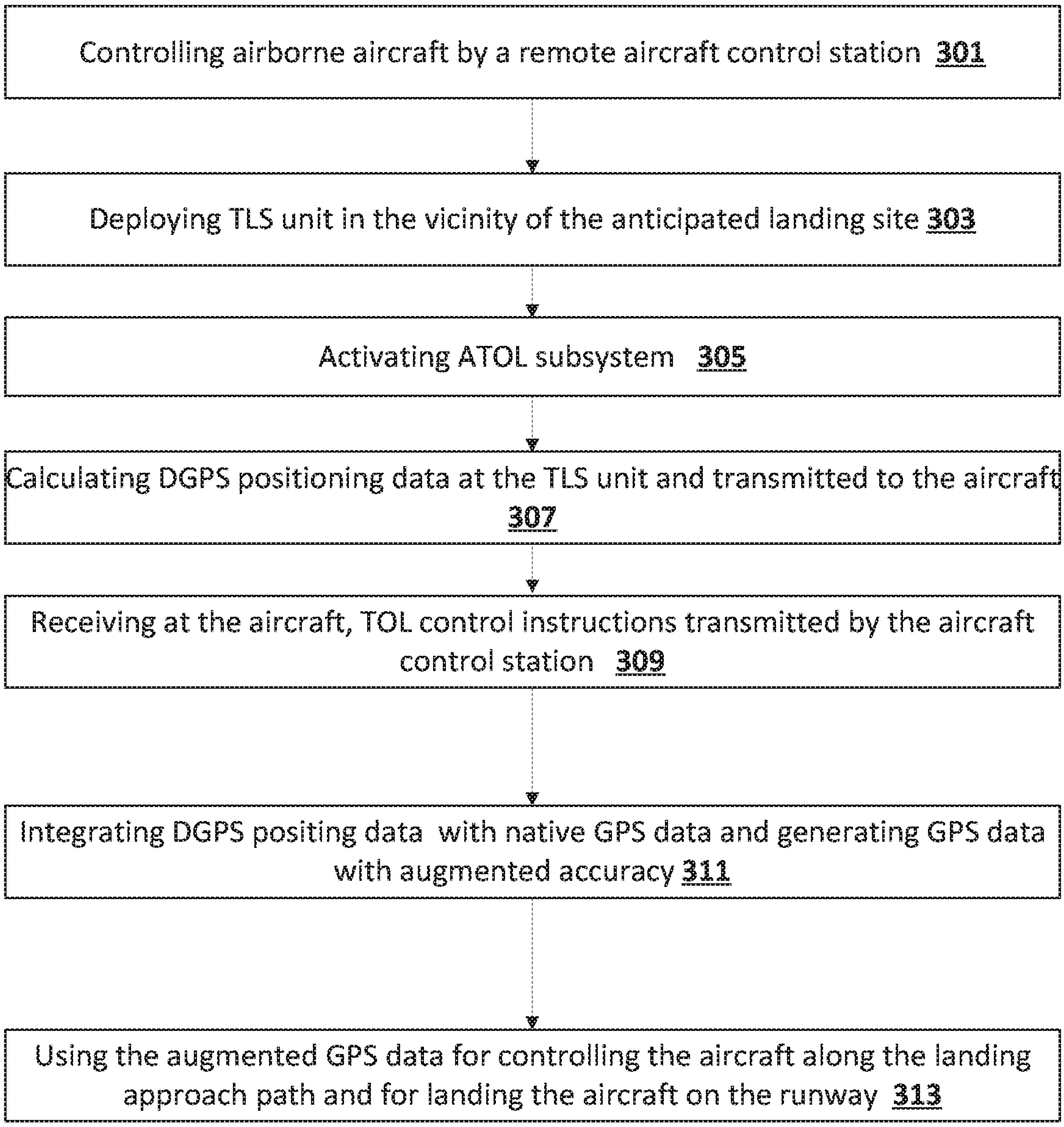


Fig. 3

PCT/IL2018/050896

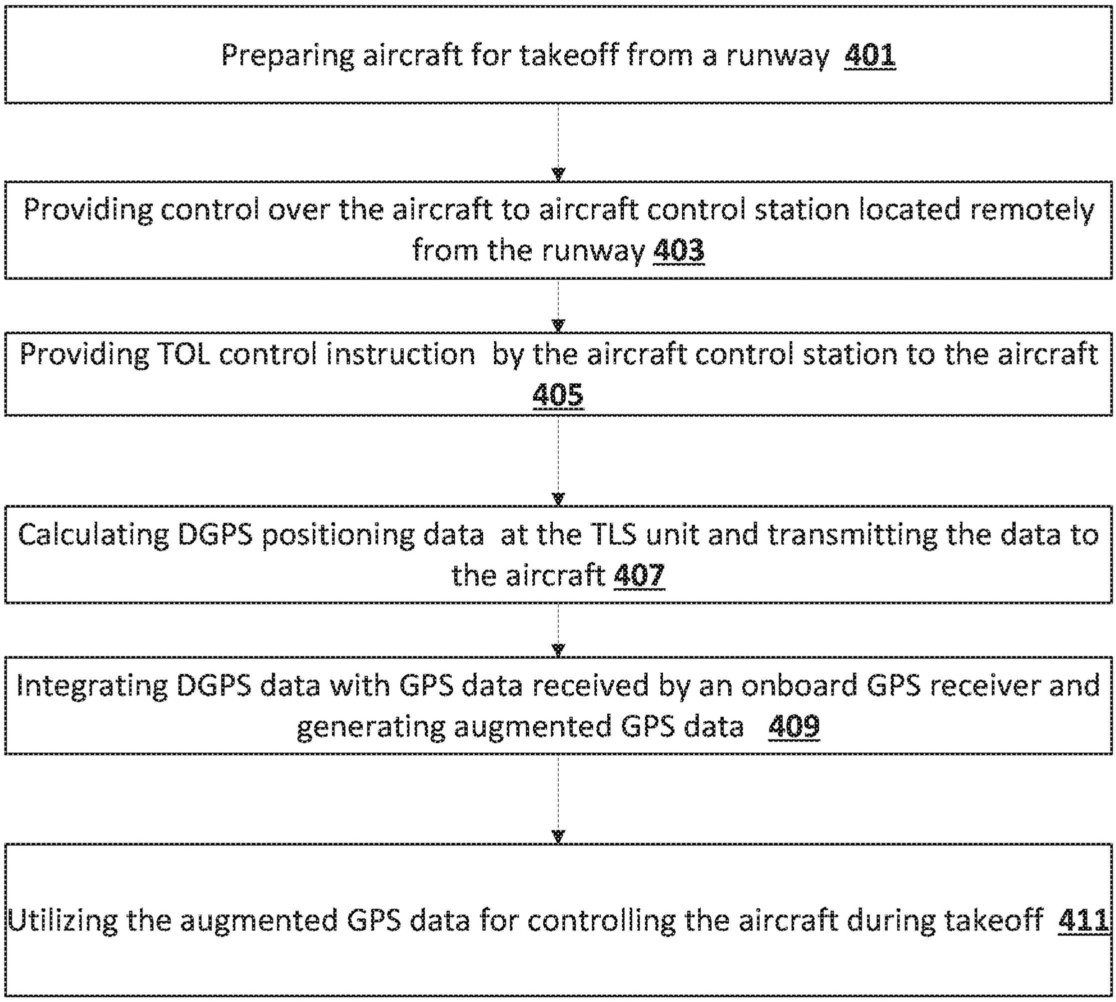
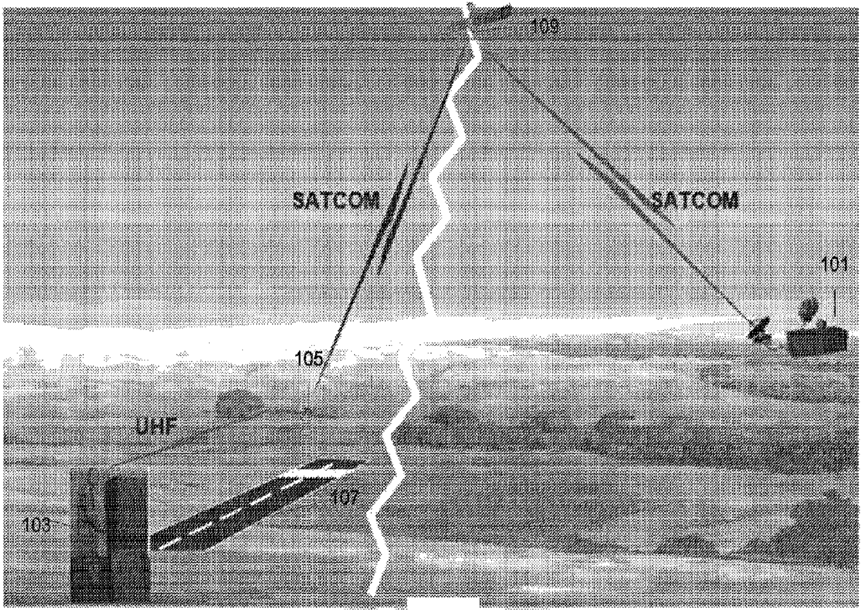


Fig. 4



109
SATCOM
SATCOM
101
105
UHF
107
103