

An Aircraft Ground Collision Warning System

FIELD OF INVENTION

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Embodiments of the present invention relate to a system and method for collision avoidance between an aircraft and surrounding objects.

10 BACKGROUND

Ground maneuvering aircraft, whether taxiing or on tow, are constantly exposed to the risk of colliding with other aircraft and/or other obstructions. A collision between an aircraft and any external object can result in tremendous costs (both tangible and non-tangible). For example, a collision between one air operator's aircraft and another operator's aircraft will lead to damages in both parties' aircraft, necessitating costly insurance claims and time consuming repair processes before the aircraft can be returned to service. In addition, after any collision, the air operator's aircraft flight schedule is likely to be affected and the air operator may have to provide an alternative schedule or may even have to pay compensation to the passengers. As a result, the loss in revenue due to the opportunity cost associated with the collision can be large even for a relatively small amount of damage, as this may be sufficient to incapacitate the aircraft. Flight delays, repair costs, aircraft downtime, insurance claims and unsatisfied customers are but a few examples from a long list of potential consequences of a collision. In some cases, human lives may even be endangered.

Collisions happen due to a lack of awareness or the misjudgment of the cockpit crew. Hence, there is a need for a system that warns the cockpit crew in the event of a possible collision so that avoidance actions can be taken to prevent a costly accident.

A number of prior art systems have been developed for collision avoidance. For example, there are some network communications systems such as the Airport Surface Map via the Automatic Dependent Surveillance-Broadcast system (ADS-B), which can provide airfield awareness to the pilots. However, these systems are
5 unable to accurately provide preemptive warnings to the aircrew of a ground maneuvering aircraft. Furthermore, the use of network communication systems, such as the ADS-B, is only effective in preventing a collision between two or more aircraft if the aircraft are equipped with the system.

10 Similarly, US Patent Publication Pub. No. (2006/0007021 A1), System and Method for Collision Avoidance, discloses a system to provide aural and visual warnings to prevent collision between a stationary aircraft and ground based service equipment. The system consists of a laser scanning assembly mounted on the fuselage at locations that are likely to come into proximity with ground support
15 equipment. However, this system has limited protection coverage and is not designed to warn the aircrew of any imminent collision with another aircraft. Furthermore, areas exposed to a high risk of potential collision, such as the wing tips and the aircraft tail assembly, are not included in the protection coverage of this system.

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US Patent Number 6,118,401, Aircraft Ground Collision Avoidance System, discloses a system that employs low cost radar and video cameras mounted on an aircraft's wing tip. These detection devices are equipped with one or more indicators to warn the aircraft operator when an imminent collision between the
25 aircraft and another object is about to occur. However, mounting radar devices on the aircraft's wing tip can introduce drag and hence, degrade the aerodynamics of the aircraft. In addition, the necessary wiring running to the fuselage and cockpit for such a system is complicated for a transport aircraft, since its wings are usually loaded with fuel. Furthermore, the radar mounted on the wing tip is designed only to
30 scan forward, abeam and aft of the wing tip, leading to a blind sector between the fuselage and the wing tip.

Figure 1 illustrates a top view of a portion of an aircraft, designated generally as reference numeral 100, equipped with an Aircraft Ground Collision Avoidance

System according to US Patent Number 6,118,401. As shown in Figure 1, the presence of the blind sector 102 between the fuselage 104 and the wing tip 106 is a result of the limited coverage provided by the radar sensor. Using radar as the sensing element may also result in Radio Frequency (RF) interference with other avionics, navigation systems and possibly airfield equipment. If the level of RF interference is to be lowered, the transmitted RF power of the radar must be attenuated, hence reducing the detection distance. This could result in an insufficient safety distance between the aircraft and the obstruction and in turn, lead to a reduction in the amount of time given for the aircrew to react to the situation.

Other sensors currently available for collision avoidance systems are also unsuitable for use in an aircraft. For example, ultrasonic sensors have been used in the collision avoidance systems of cars. However, the range of these ultrasonic sensors is short. Additionally, engine noise or other external sounds can degrade the performance of these sensors. Hence, they are not suitable for use in a collision avoidance system of an aircraft. Another type of sensor often employed in collision avoidance systems is the infrared sensor. However, they are not suitable for use in strong sunlight and hence, cannot be used on an aircraft, which must operate under variable lighting conditions.

To date, there is no system that can operate independently with minimum RF interference and without modifications to the aircraft airframe, and yet at the same time, provide reliable and accurate early warning to the cockpit operators in order to avoid ground collision. Accordingly, there is a significant need for an improved early warning system that can overcome one or more of the problems discussed above.

SUMMARY

A first aspect of the present invention provides a system for collision avoidance between an aircraft and surrounding objects on the ground, the system includes a controller interface; a plurality of laser sensors mounted on the aircraft and electrically connected to the controller interface, each of the plurality of laser sensors having a detection area, such that said detection areas cumulatively cover at least a periphery of both a left and a right wing of the aircraft; audio and visual

warning means located in a cockpit of the aircraft, each of the audio and visual warning means being electrically connected to the controller interface; and at least one video camera mounted on the aircraft and electrically connected to the controller interface, such that when said at least one video camera is activated, said video camera provides an image of said periphery to said visual warning means; wherein the controller interface receives a signal from at least one of the laser sensors indicating the presence of an object within the detection area and activates at least one of the audio warning means and said at least one video camera to alert an operator of the aircraft that a collision is possible.

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The controller interface may further include a controller board, an audible warning generator, and a relay board. The plurality of laser sensors may further include at least one laser sensor mounted on a fuselage of the aircraft forward of a leading edge of each of the left-hand and right-hand wings at a position higher than that of the wings; at least one laser sensor mounted on a fuselage of the aircraft behind a trailing edge of each of the left-hand and right-hand wings at a position higher than that of the wings; at least one laser sensor mounted on a fuselage of the aircraft behind a trailing edge of each of the left-hand and right hand horizontal stabilizers at a position higher than that of the horizontal stabilizer; and at least one laser sensor mounted on a fuselage of the aircraft at the aircraft tail.

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The laser sensors mounted forward of and behind the wings, and the laser sensors mounted behind the horizontal stabilizer, may be mounted symmetrically with respect to each other. The plurality of laser sensors may be adjusted to provide at least a three second warning to the operator.

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The at least one video camera mounted on the aircraft may further include a first video camera mounted on a vertical fin of the aircraft that is capable of providing video coverage for the right side of the aircraft; and a second video camera mounted on the vertical fin of the aircraft that is capable of providing video coverage for the left side of the aircraft.

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The audio warning means may be selected from a group consisting of a buzzer, a bell, and a tone. The visual warning means may comprise at least one

video display unit capable of receiving images from said at least one video camera. The display unit may further include one of a navigation display or a Class III Electronic Flight Bag. The audio and visual warning means may further include a pair of annunciators.

The system may further include a warning indicator that is powered on by the controller interface when a faulty laser sensor is detected by a controller board in the controller interface.

A second aspect of the present invention provides a method for collision avoidance between an aircraft and surrounding objects, the method including the steps of providing a controller interface; providing a plurality of laser sensors mounted on the aircraft and electrically connected to the controller interface, each of the plurality of laser sensors having a detection area, such that said detection areas cumulatively cover at least a periphery of both a left and a right wing of the aircraft; providing audio and visual warning means located in a cockpit of the aircraft, each of the audio and visual warning means being electrically connected to the controller interface; providing at least one video camera mounted on the aircraft and electrically connected to the controller interface, such that when said at least one video camera is activated, said video camera provides an image of said periphery to said visual warning means; and activating at least one of said audio warning means and said at least one video camera when the controller interface receives a signal from at least one of said plurality of laser sensors that has detected an object within the detection area to alert an operator of said aircraft that a collision is possible.

The method may further include a step for determining a predetermined detection distance for each of said plurality of laser sensors prior to said activating step. The determining step may further include determining said predetermined detection distance based on at least one of a response and reaction time of a pilot, a braking distance of the aircraft, a taxi speed of the aircraft, and a minimum clearance distance between the aircraft and a detected object.

The step of providing at least one video camera may further include the steps of providing a first video camera mounted on a vertical fin of the aircraft that is

capable of providing video coverage for the right side of the aircraft; and providing a second video camera mounted on the vertical fin of the aircraft that is capable of providing video coverage for the left side of the aircraft.

5 The step of providing a plurality of laser sensors may further include providing a laser sensor mounted on a fuselage of the aircraft forward of a leading edge of each of the left-hand and right-hand wings at a position higher than that of the wings; providing a laser sensor mounted on a fuselage of the aircraft behind a trailing edge of each of the left-hand and right-hand wings at a position higher than
10 that of the wings; providing a laser sensor mounted on a fuselage of the aircraft behind a trailing edge of each of the left-hand and right hand horizontal stabilizers at a position higher than that of the horizontal stabilizer; and providing at least one laser sensor mounted on a fuselage of the aircraft at the aircraft tail.

15 The audio and visual warning means may include at least one annunciator, and the method may further include the steps of: displaying a warning messages on said at least one annunciator as part of said activating step. The method may further include the steps of: detecting a faulty laser sensor; and powering on a warning indicator to indicate the location of the faulty laser sensor. The method may further
20 include a step for maneuvering the aircraft according to a location provided by the audio and visual warning means to avoid collision between the aircraft and an object in the vicinity of said location.

25 **BRIEF DESCRIPTION OF THE DRAWINGS**

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

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Figure 1 illustrates a top view of a portion of an aircraft equipped with an Aircraft Ground Collision Avoidance System according to the prior art;

Figure 2 illustrates a schematic block diagram of an aircraft Ground Collision Warning System according to one embodiment of the present invention;

5 Figure 3 illustrates a portion of the Ground Collision Warning System of Figure 2 installed in a cockpit of an aircraft;

Figure 4 illustrates a top view of an aircraft, showing one embodiment of possible locations for the sensors of the system of Figure 2;

10 Figure 5 illustrates a front view of a portion of the aircraft of Figure 4;

Figure 6 illustrates a top view of an aircraft, showing one embodiment of the possible locations for the cameras of the system of Figure 2;

15 Figure 7 illustrates a top view of the aircraft of Figure 6, showing possible coverage provided by the cameras;

Figure 8 illustrates a side view of the aircraft of Figure 7; and

20 Figure 9 illustrates a partial top view of the aircraft of Figures 4 and 5, showing possible safety distances provided by the sensors.

DETAILED DESCRIPTION

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The example embodiments of the present invention provide an aircraft Ground Collision Warning System (GCWS) to assist cockpit crew to avoid collisions between the aircraft and surrounding objects.

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Figure 2 illustrates a schematic block diagram of an aircraft GCWS, designated generally as reference numeral 200, according to one embodiment of the present invention. The GCWS 200 can include a control panel 202 located in the pilots' cockpit (See Figure 3), a controller interface 204, a plurality of laser sensors 206 and one or more video cameras 208. In some embodiments, the

sensors 206 can be located on the fuselage 402 of an aircraft 400 (See Figures 4 and 5) whereas the cameras 208 can be located on the vertical fin 604 of the aircraft 400 (See Figure 6). The sensors 206 can detect objects that are within a stipulated safety distance from the aircraft 400 and, upon detecting such objects, send a signal to the controller interface 204. The controller interface 204 can include a controller board 210 and a relay board 212 for relaying signals between the sensors 206, cameras 208 and the cockpit control panel 202. The controller interface 204 can also include an audible warning generator 220. The cockpit control panel 202 can include a master control 218 and a warning system. The warning system may include equipment such as an audible warning device 214 and/or a display 216, providing aural and/or visual warnings to the cockpit crew. The master control 218 in the cockpit control panel 202 can control various components such as the on/off switches, volume and intensity controls of the video display 216 and/or the audible warning device 214. In some embodiments, the audible warning device 214 may include one or more buzzers, bells, tones, etc. to alert the cockpit crew of the possibility that a collision is imminent. The audible warning device may be incorporated into the control panel 202, or may be located elsewhere within the cockpit of the aircraft.

Figure 3 illustrates a portion of the GCWS 200 of Figure 2 installed in a cockpit of an aircraft. The control panel 202 can include a warning system that may include equipment such as the audible warning device 214 and the display 216, so as to provide both aural and visual warnings to the cockpit crew. The display 216 provides the capability to show real time video images from the cameras 208 (as seen in Figure 6). In some embodiments, the display 216 may be the navigation display or the Class III Electronic Flight Bag (EFB) display of the Captain and/or the First Officer. Similarly, the audible warning device 214 may include an external speaker and/or be incorporated within the pilot's headset. The audible warning device 214 may be located on the control panel 202, or elsewhere in the cockpit of the aircraft.

In some embodiments, the GCWS 200 may also include one or more annunciators 304, located, for example, on the cockpit control panel 202, or elsewhere in the cockpit of the aircraft. The annunciators 304 may display warning messages to the

cockpit crew and may indicate the side of the aircraft that is exposed to the risk of collision. In some embodiments, the warning message may be a lighted display showing, by way of example and not limitation, text such as "collision imminent" or other appropriate warning text. The annunciator 304 may alternately be a simple
5 warning light within the cockpit. The annunciators 304, camera(s) 208, and display 216 provide examples of visual warning means that form part of the system 200.

Figure 4 illustrates a top view of an aircraft, designated generally as reference numeral 400, showing one embodiment of possible locations for the
10 sensors 206 of the GCWS 200 of Figure 2. Figure 5 illustrates a front view of a portion of the aircraft 400 of Figure 4. In the example illustrated in Figures 4 and 5, the GCWS 200 includes seven sensors 206 on the fuselage 402. However, it is understood that the GCWS 200 may include more than seven sensors.

15 As shown in Figure 4, two of the sensors, 206A and 206B, can be located forward of the leading edge of the left-hand wing 406 and the right-hand wing 408 respectively. Sensors 206C and 206D can be located behind the trailing edge of the left-hand wing 406 and the right-hand wing 408 respectively. Sensors 206E and 206F can be located at the rear of the trailing edge of the horizontal stabilizer 410.
20 Lastly, sensor 206G can be located at the aircraft tail 412. It is understood that many other specific sensor locations are possible, depending on the type of aircraft and the amount of coverage desired. The illustrated embodiment is provided by way of example only. The present invention is, therefore, not limited to the embodiments shown in the drawings.

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As shown in Figure 5, sensors 206A, 206B, 206C and 206D (as seen in Figure 4) can be mounted at a position 502 higher than that of the main wing 406. Sensors 206E and 206F can be mounted at a position 504 higher than that of the horizontal stabilizer 410. The positions 502 and 504 can be set so as to provide a
30 line of sight or a field of view for the sensors 206 to cover various components of the aircraft 400. Figure 5 shows only one side of the aircraft 400 for descriptive purposes. However, it is understood that the placement of the sensors 206 on the aircraft starboard side may be symmetrical to the placement of the sensors 206 on the aircraft portside.

Figure 6 illustrates a top view of the aircraft 400, showing one possible location for the cameras 208 of the GCWS 200. In Figure 6, the GCWS 200 includes two cameras, 208A and 208B, mounted on top of each other in the same housing. However, it is possible for the GCWS 200 to include a larger or smaller number of cameras in either the same or separate housings. In the example shown in Figure 6, the cameras 208 are mounted on the vertical fin 604. One of the cameras 208A provides a view of the right side of the aircraft 400 whereas the other camera 208B provides a view of the left side of the aircraft 400.

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Figure 7 illustrates a top view of the aircraft 400 of Figure 6, showing possible coverage provided by the cameras 208 of the GCWS 200. In the example in Figure 7, the dotted lines 702 illustrate one possible coverage area provided by the camera 208A on the aircraft right side, whereas the dotted lines 704 illustrate one possible coverage area provided by the camera 208B on the left side of the aircraft. In addition, Figure 8 illustrates a side view of the aircraft 400 of Figure 7, showing a top down view of one possible coverage area 802 provided by the cameras 208. Both Figures 7 and 8 show the wide coverage of the aircraft 400 provided by the cameras 208 of the GCWS 200, according to one embodiment of the present invention. Although Figure 8 shows only the left side view of the aircraft 400 for descriptive purposes, it is understood that the coverage provided by the cameras 208 may be symmetrical on both sides of the aircraft 400.

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Figure 9 illustrates a partial top view of the aircraft 400 of Figures 4 and 5, showing possible safety distances provided by the sensors 206 of the GCWS 200. The sensors 206 can cumulatively provide azimuth protection coverage of the wings 406 and 408, vertical stabilizer 604, horizontal stabilizer 410 (as seen in Figure 6) and the aircraft tail 412. The safety distances shown in Figure 9 may be affected by factors such as the range of the sensors 206, the mounting location of the sensors 206, and the specific angles at which the sensors 206 are oriented. Although Figure 9 shows only a portion of the aircraft 400 for descriptive purposes, it is understood that the safety distances on the aircraft portside can be symmetrical to the safety distances on the aircraft starboard side.

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In one embodiment, sensor 206A can be pointed at an angle that provides W 902 meters of safety clearance in front of and H 914 meters beyond, the tip 910 of the wing 406. Sensor 206C can be pointed at an angle that provides X 904 meters of safety clearance behind and H 914 meters beyond the tip 910 of the wing 406.

5 Sensors 206E and 206F can be pointed at an angle that provides Y 906 meters of safety clearance behind and J meters 916 beyond the middle 912 of the horizontal stabilizer 410. Sensor 206G can be pointed directly aft of the aircraft 400, providing Z 908 meters of safety clearance behind the tail 412 of the aircraft 400. These distances W 902, X 904, Y 906, Z 908, H 914 and J 916 can be calculated based on

10 factors such as the aircraft platform type, the typical human response and reaction time, the braking distance of the forwarding taxiing or reverse towing aircraft or the nominal towing and taxiing speed.

Equations (1) – (3) below illustrate sample calculations of some of the above

15 distances, W, X, Y, Z, J, and H.

The safety distance (Safety Distance₁(km)) required taking into account only the Pilot's Response Time(s) i.e., the time taken for the pilot to react after a foreign object near the aircraft is detected, may be calculated according to Equation (1)

20 assuming that the aircraft is taxiing at a speed equal to the Travelling Speed (km/hr) indicated in Equation (1).

$$\text{Safety Distance}_1(\text{km}) = \frac{\text{Travelling Speed (km/hr)}}{3600} \times \text{Pilot's Response Time(s)} \quad (1)$$

25 The safety distance (Safety Distance₂(km)) required taking into account only the Aircraft's Reaction Time(s) i.e., the time taken for the aircraft to decelerate after a foreign object near the aircraft is detected, and the aircraft operator takes appropriate action to slow or turn the aircraft, is calculated according to Equation (2) assuming that the aircraft is taxiing at a speed equal to the Travelling Speed (km/hr)

30 indicated in Equation (2).

$$\text{Safety Distance}_2(\text{km}) = \frac{\text{Travelling Speed (km/hr)}}{3600} \times \text{Aircraft's Reaction Time(s)} \quad (2)$$

The total safety distance (Safety Distance_{Total}(km)) may take into account both the Pilot's Response Time and the Aircraft's Reaction Time according to Equation (3). In addition, it may also include a safety margin which provides a buffer distance from the foreign object to the aircraft after considering the Pilot's Response Time and the Aircraft's Reaction Time. In some embodiments, the Safety Margin may be dependent on the type of aircraft, or other specific requirements dictated by particular airports, etc.

$$\text{Safety Distance}_{\text{Total}}(\text{km}) = (\text{Safety Distance}_1(\text{km}) + \text{Safety Distance}_2(\text{km})) \times \text{Safety Margin}(\%) \quad (3)$$

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With reference to Figure 9, W 902 is the forward leading distance from the aircraft wings, X 904 is the trailing distance behind the aircraft wings as measured from the wing tips. Y 906 is the distance measured from the middle 912 of the trailing edge of the horizontal stabilizer 410, and Z 908 is the distance referenced from the end of the aircraft. The Distances W 902, X 904, Y 906 and Z 908 may be greater than or equal to the total safety distance (Safety Distance_{Total}) calculated according to Equation (3). The distance J 916 is measured from the centerline 918 of the aircraft to the middle of the horizontal stabilizer 410. The distance H 914 may be determined based on, for example, regulatory requirements from an authority body, such as the minimum safety distance for a Taxiway, other than an aircraft stand taxi lane, measured from the centre line of the aircraft to the object. Furthermore, the calculation of distances X 904, Y 906, Z 908 and J 916 may be based on the traveling speed of the aircraft when it is being reverse towed. On the other hand, the calculation of distance W 902 may be based on the traveling speed of the aircraft when it is maneuvering forward. The traveling speed at which the aircraft maneuvers forward is usually greater than the speed at which it is being reverse towed. The sensors can then be calibrated based on distances W 902, X 904, Y 906, Z 908, H 914 and J 916.

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Table 1

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Aircraft Traveling Speed (km/hr)	5
Pilot Response and Reaction Time (s)	3
Aircraft Reaction Time (s)	2
Safety Margin (%)	30
Safety Distance ₁ (km)	0.0042
Safety Distance ₂ (km)	0.0028
Safety Distance _{Total} (km)	0.0091

With respect to the issues identified above, Table 1 shows an example of the calculation of the safety distances in Equations (1) – (3) for a Boeing 777 aircraft being reverse towed. Table 1 shows an aircraft traveling speed of 5km/hr, a response/reaction time for the pilots of 3 seconds, an aircraft reaction time of 2 seconds and a safety margin of 30%. Applying the formulas discussed above, This results in a total safety distance (Safety Distance_{Total}) of 0.0091km with a safety margin of 30%. Thus, in the example shown in Table 1, W 902, X 904, Y 906 and Z 908 can be set to a value greater than or equal to 0.0091km. In addition, H can be set to 47.5m since the Boeing 777 aircraft requires a minimum clearance of 47.5m. It is understood that different aircraft traveling speeds, pilot's reaction times, aircraft reaction times and safety margins can be used. It is also understood that similar calculations can be made for other types of aircraft.

With reference to Figures 2-9, one example illustrating the specific operating characteristics of the embodiment of the GCWS 200 will now be discussed. The sensors 206, upon detecting foreign objects at pre-determined safety distances (W 902, X 904, Y 906, Z 908, H 1002 or J 1004), may send a current output to the controller interface 204. Upon receiving the current output, the controller board 210 in the controller interface 204 may then command the relay board 212 in the controller interface 204 to energize its relays. Voltage supply may then be routed through the relay board 212 to turn on the audible warning generator 220 in the controller interface 204. Concurrently or successively, the cameras 208 may be turned on via the voltage supply routed through the relay board 212. The audio signals from the audible warning generator 220 and the video signals from the cameras 208 may then be transmitted to the master control 218. Subsequently, these audio and video signals may be transmitted from the master control 218 to the

audible warning device 214, the display 216, and the annunciators 304, respectively, providing real time displays of portions of the aircraft 400 and aural warnings to the aircraft crew. The aircraft crew may control various components such as the on/off switches, volume and intensity controls of the video display 216 and/or the audible
5 warning device 214 using the master control 218 in the cockpit control panel 202. Each sensor 206 may be associated with a camera 208. For example, sensors activated on the port side may activate camera 208A, while sensors activated on the starboard side may activate camera 208B. This allows the camera 208 to provide a real time display of the area covered by its associated sensor(s) 206. The audible
10 warning device 214 and display 216 may be common to all the sensors 206 and cameras 208. In alternate embodiments, different audible warnings may be activated depending on which sensor 206 is activated. These audible warnings may be pre-set warning tones, bells, buzzers, etc.

15 In one embodiment, the following events take place in the cockpit when a sensor 206 detects an object within the sensor range. The audible warning device 214 sounds. The view of the side of the aircraft 400 where the object is detected is then captured by one or more of the cameras 208 and is shown on the display 216. In some embodiments, the control panel 202 may also include a pair of annunciators
20 304. These annunciators 304 may display a warning message such as "COLLISION IMMINENT" in amber. The annunciator 304 on the side of the aircraft 400, where the collision may occur, may illuminate and flash. These aural and visual alarms alert the cockpit crew and notify them that one or more of the safety distances (W 902, X 904, Y 906, Z 908, H 1002 or J 1004) have been infringed.

25 In some embodiments, if a sensor 206 becomes faulty at any point in time, the controller 210 can detect the faulty sensor 206 and a warning indicator can be lit to indicate the location of the faulty sensor 206. This serves to warn the cockpit crew of any blind sector created due to the sensor failure.

30 The sensors 206 in one example, may be Class 1 laser sensors with a measuring range of 0.5m to 300m. This type of laser sensor may emit a non-visible laser beam and, being Class 1, is considered safe to the human eye. Furthermore, the laser sensors 206 should be able to measure distance and speed of natural

targets without a reflector. They have a broad working range and require very short times to perform the measurement. Therefore, such sensors are suitable for use on an aircraft GCWS 200. However, in alternate embodiments of the GCWS 200, other types of sensors 206 may also be used. Similarly one or more of the sensors 206
5 within one GCWS 200 may be of different models or types.

The cameras 208 in one example, are video cameras with a fixed lens and auto iris colour feature. In addition, they may be of aerodynamic design. Hence, the presence of the cameras 208 has a minimal effect on the aerodynamics of the
10 aircraft 400. In alternate embodiments of the GCWS 200, other models of cameras 208 may be used.

The example embodiments of the present invention provide several advantages over prior art systems. The laser sensors in the GCWS have a sufficiently long sensing
15 range and a sufficiently large beam diameter to offer protection to areas that are exposed to a high risk of collision. These areas are for example, the wing tips and the tail assembly. Furthermore, the GCWS provides protection coverage of the entire wing and not just the wing tip when the sensors of the GCWS are mounted on the fuselage and are aimed towards the wing tips.

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The GCWS does not require another aircraft and/or objects to be equipped with the same system to function. It can provide collision warnings entirely on a stand-alone basis. Utilising a laser proximity sensor, the GCWS is able to provide warning prior to a ground collision without introducing RF interference. Embodiments of the GCWS are
25 designed to introduce minimum modifications to existing avionics and aircraft aerodynamics.

The GCWS incorporates cameras that are coupled to the sensors. When a possible collision is detected, the camera is powered on and the captured video image
30 will be displayed on a monitor in the cockpit. This enhances the ability of the cockpit crew in deciding if it is safe for continued maneuvering and whether it is necessary to take action to avoid a collision. This in turn lowers the unnecessary costs and the number of lives that may be lost due to a collision. Lastly, the GCWS may operate entirely on aircraft battery power and can be activated anytime when the aircraft is

on the ground through an aircraft-on-ground sensing switch. Hence it is operational regardless of whether the aircraft is taxiing or on tow. Once the aircraft is airborne, the GCWS may be deactivated.

- 5 It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A system for collision avoidance between an aircraft and surrounding objects on the ground, the system comprising:

5 a controller interface;

a plurality of laser sensors mounted on the aircraft and electrically connected to the controller interface, each of the plurality of laser sensors having a detection area, such that said detection areas cumulatively cover at least a periphery of both a left and a right wing of the aircraft;

10 audio and visual warning means located in a cockpit of the aircraft, each of the audio and visual warning means being electrically connected to the controller interface; and

at least one video camera mounted on the aircraft and electrically connected to the controller interface, such that when said at least one video camera is activated, said video camera provides an image of said periphery to said visual warning means;

15 wherein the controller interface receives a signal from at least one of the laser sensors indicating the presence of an object within the detection area and activates at least one of the audio warning means and said at least one video camera to alert an operator of the aircraft that a collision is possible.

- 20 2. The system as claimed in claim 1, wherein the controller interface further comprises a controller board, an audible warning generator, and a relay board.

- 25 3. The system as claimed in claims 1 or 2, wherein the plurality of laser sensors further comprises:

30 at least one laser sensor mounted on a fuselage of the aircraft forward of a leading edge of each of the left-hand and right-hand wings at a position higher than that of the wings;

at least one laser sensor mounted on a fuselage of the aircraft behind a trailing edge of each of the left-hand and right-hand wings at a position higher than that of the wings;

at least one laser sensor mounted on a fuselage of the aircraft behind a trailing edge of each of the left-hand and right hand horizontal stabilizers at a position higher than that of the horizontal stabilizer; and

at least one laser sensor mounted on a fuselage of the aircraft at the aircraft tail.

4. The system of claim 3, wherein the laser sensors mounted forward of and behind the wings, and the laser sensors mounted behind the horizontal stabilizer, are mounted symmetrically with respect to each other.
5. The system as claimed in any one of the preceding claims, wherein the plurality of laser sensors are adjusted to provide at least a three second warning to the operator.
6. The system as claimed in any one of the preceding claims, wherein the at least one video camera mounted on the aircraft further comprises:
 - a first video camera mounted on a vertical fin of the aircraft that is capable of providing video coverage for the right side of the aircraft; and
 - a second video camera mounted on the vertical fin of the aircraft that is capable of providing video coverage for the left side of the aircraft.
7. The system as claimed in any one of the preceding claims, wherein the audio warning means is selected from a group consisting of a buzzer, a bell, and a tone.
8. The system as claimed in any one of the preceding claims, wherein the visual warning means comprises at least one video display unit capable of receiving images from said at least one video camera.
9. The system as claimed in claim 8, wherein the display unit further comprises one of a navigation display or a Class III Electronic Flight Bag.
10. The system as claimed in any one of the preceding claims, wherein the audio and visual warning means further comprises a pair of annunciators.

11. The system as claimed in any one of the preceding claims, further comprising a warning indicator that is powered on by the controller interface when a faulty laser sensor is detected by a controller board in the controller interface.
12. A method for collision avoidance between an aircraft and surrounding objects, the method comprising the steps of:
 - providing a controller interface;
 - providing a plurality of laser sensors mounted on the aircraft and electrically connected to the controller interface, each of the plurality of laser sensors having a detection area, such that said detection areas cumulatively cover at least a periphery of both a left and a right wing of the aircraft;
 - providing audio and visual warning means located in a cockpit of the aircraft, each of the audio and visual warning means being electrically connected to the controller interface;
 - providing at least one video camera mounted on the aircraft and electrically connected to the controller interface, such that when said at least one video camera is activated, said video camera provides an image of said periphery to said visual warning means; and
 - activating at least one of said audio warning means and said at least one video camera when the controller interface receives a signal from at least one of said plurality of laser sensors that has detected an object within the detection area to alert an operator of said aircraft that a collision is possible.
13. The method of claim 12, further comprising a step for determining a predetermined detection distance for each of said plurality of laser sensors prior to said activating step.
14. The method of claim 13, wherein said determining step further comprises determining said predetermined detection distance based on at least one of a response and reaction time of a pilot, a braking distance of the aircraft, a taxi

speed of the aircraft, and a minimum clearance distance between the aircraft and a detected object.

15. The method as claimed in any one of claims 12 – 14, wherein the step of
5 providing at least one video camera further comprises the steps of:

providing a first video camera mounted on a vertical fin of the aircraft
that is capable of providing video coverage for the right side of the aircraft;
and

10 providing a second video camera mounted on the vertical fin of the
aircraft that is capable of providing video coverage for the left side of the
aircraft.

16. The method as claimed in any one of claims 12 – 15, wherein the step of
providing a plurality of laser sensors further comprises:

15 providing a laser sensor mounted on a fuselage of the aircraft forward
of a leading edge of each of the left-hand and right-hand wings at a position
higher than that of the wings;

20 providing a laser sensor mounted on a fuselage of the aircraft behind
a trailing edge of each of the left-hand and right-hand wings at a position
higher than that of the wings;

providing a laser sensor mounted on a fuselage of the aircraft behind
a trailing edge of each of the left-hand and right hand horizontal stabilizers at
a position higher than that of the horizontal stabilizer; and

25 providing at least one laser sensor mounted on a fuselage of the
aircraft at the aircraft tail.

17. The method as claimed in any one of claims 12 – 16, wherein the audio and
visual warning means comprises at least one annunciator, and said method
30 further comprises the steps of:

displaying a warning messages on said at least one annunciator as
part of said activating step.

18. The method as claimed in any one of claims 12 – 17, further comprising the steps of:
- detecting a faulty laser sensor; and
 - powering on a warning indicator to indicate the location of the faulty laser sensor.
19. The method as claimed in any one of claims 12 – 18, further comprising a step for maneuvering the aircraft according to a location provided by the audio and visual warning means to avoid collision between the aircraft and an object in the vicinity of said location.
20. The system of any one of claims 1-11, wherein said plurality of laser sensors comprises seven sensors mounted on a fuselage of the aircraft and said detection areas cumulatively cover an entire periphery of the aircraft.
21. The system of any one of claims 1-11 and 20, wherein the warning means are activated such that the operator has at least five seconds to avoid said possible collision.
22. The method of any one of claims 12-19, wherein said plurality of laser sensors comprises seven sensors mounted on a fuselage of the aircraft and said detection areas cumulatively cover an entire periphery of the aircraft.
23. The method of any one of claims 12-19 and 22, wherein the warning means are activated such that the operator has at least five seconds to avoid said possible collision.