

IMPROVED LASER BASED VISUAL LANDING AIDS AND METHOD FOR  
IMPLEMENTING SAME

Technical Field

5       The present invention relates to methods and apparatus for  
aiding landing aircraft, and more particularly, landing aids for  
better defining landing corridor azimuths and for separating  
parallel runways for sea- and land-based approach aids, and  
portable solar powered installations.

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Background of the Invention

15       The prior art discloses laser based aids to navigation,  
with particular application to landing, which use a series of  
low power visible lasers to illuminate corridors of sky which  
define the proper approach path. In the basic embodiment the  
system uses three colors: Amber (or yellow) to indicate on  
course, red to indicate left of course, and green to indicate  
right of course. In addition when well left or right of course  
the colors are made to blink, first slow and then fast.

20       There are two such systems. One defines the extended  
centerline of the landing area and the other defines the proper  
glideslope. In practice there are aspects of the basic design  
which are not optimal, and specific additions and delineations  
which improve the overall performance of the system are  
25       desirable. In particular, it is possible for the flashing  
corridors to become confused with aircraft beacons or other  
flashing lights which are known to be found in the vicinity of  
the approach corridor. Also, modifications to the corridor size  
produce better approach performance by optimizing the match  
30       between corridor size and aircraft flight characteristic.  
Further, light scattering from the lens of the exit aperture of  
the current art design can cause distractions to the pilot  
during the final stages of the approach. Still further,  
modifications to the basic design disclosed in this patent  
35       provide for greater ease in maintenance by allowing easy and  
exact replacement of laser which is necessary due to the limited  
lifetime of the laser, and changes to the optical design allows  
for easier and more cost effective manufacturing.

### Summary of the Invention

According to one aspect, the invention is a visual aid for azimuthal guidance of landing aircraft. The aid defining landing corridors, including a central fan-shaped corridor and second, third, fourth and fifth corridors. The central corridor is continuously filled with a first color of light. The second and third fan-shaped corridors are adjacent the two fan-shaped surfaces of the central corridor and are respectively continuously filled with second and third colors of light which differ from the first color of light. The fourth and fifth fan-shaped corridors are respectively adjacent the two fan-shaped surfaces of the second and third corridors and are respectively intermittently filled with the second and third colors of light at a first rate.

According to a second aspect, the invention is a method for producing a visual aid for azimuthal guidance of landing aircraft. The method includes the steps of a) providing a central fan-shaped corridor continuously filled with a first color of light and b) providing second and third fan-shaped corridors adjacent the two fan-shaped surfaces of the central corridor, the second and third corridors being respectively continuously filled with second and third colors of light which differ from the first color of light. The method also includes the steps of c) providing fourth and fifth fan-shaped corridors respectively adjacent the two fan-shaped surfaces of the second and third corridors, the fourth and fifth corridors being respectively intermittently filled with the second and third colors of light at a first rate, and d) providing sixth and seventh fan-shaped corridors respectively adjacent the two fan-shaped surfaces of the fourth and fifth corridors, the sixth and seventh corridors being respectively intermittently filled with the second and third colors of light at a second rate that is different from the first rate.

### Brief Description of the Drawings

Figure 1 is a schematic diagram of a laser visual landing aid corridor design for azimuthal guidance for an approach to an aircraft carrier.

Figure 2 is a schematic diagram of a laser visual landing aid corridor design for azimuthal guidance for an approach to a land-based landing field.

Figure 3 is a schematic diagram of a laser visual landing aid corridor design for azimuth guidance for an approach to a helicopter landing pad.

Figure 4 is a schematic diagram showing the temporal pattern of the dot-dash flash rate for both the slowly flashing and rapidly flashing corridors.

Figure 5 is a schematic diagram of the optical beam train for a single laser corridor.

Figure 6 is a schematic diagram of the laser mounting cassette of the inventive system, showing the precision expanding latching pins, and the tangs and clevis.

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#### Detailed Description of the Preferred Embodiments of the Invention

According to one aspect, the invention is a series of improvements to laser based visual landing aids which makes the devices optimal and manufacturable. The first aspect is a construction of corridor angular widths which optimize the interception of the centerline by the approaching aircraft and optimize the subsequent centerline tracking. This is accomplished by using a specific non-linear sequence of corridor width designed around the specific behavior of the aircraft in a given environment.

For the purposes of this invention we will consider three different environments: the aircraft carrier, land-based landing field, and helicopter landing zone both land- and sea-based.

Figure 1 is a schematic diagram of a laser visual landing aid corridor design for azimuthal guidance for an approach to an aircraft carrier. In the case of the aircraft carrier environment the optimal configuration for the approach corridors is the following, the corridors being shown from above emanating from the stern 1 of the aircraft carrier. Beginning with an amber centerline (first) corridor 10, the azimuthal angular width should be 0.5 degrees plus or minus 0.1 degrees. Adjacent to the centerline corridor 10 are red (first) and green (second) corridors (11 and 12, respectively) which are adjacent to the

fan surfaces of the centerline corridor 10 and 0.8 degrees wide in azimuth (plus or minus 0.1 degree). The corridors 10-12 are continuously illuminated and not interrupted temporally. Adjacent to either of the steady red or steady green corridors 11 and 12, respectively, and further outboard of the centerline corridor 10 are respectively red (fourth) and green (fifth) corridors (13 and 14, respectively) which are interrupted by a conventional mechanical chopper or under control of an electrical signal which causes the fourth and fifth corridors 13 and 14 to appear to flash a periodic pattern at a slow rate (say, 35-40 times per minute). The optimal angular thickness of the fourth and fifth corridors 13 and 14 is approximately 3.0 degrees with 10% variations. Finally, adjacent to the slowly flashing fourth and fifth corridors 13 and 14 (and further outboard from the centerline corridor 10) are respective red and green (i.e., sixth and seventh) corridors 15 and 16 which are interrupted in such a way as to make them appear to flash a periodic pattern rapidly relative to the slowly flashing fourth and fifth corridors 13 and 14 (such as the conventional chopper or electrical signal control described above). The azimuthal angular widths of these sixth and seventh corridors 15 and 16 are approximately 6.0 degrees, plus or minus 10%. All of the corridors 11-16 have an angular height (in elevation) of 4 to 5 degrees. In addition, the elevation of the upper edge of the corridors 11-16 is set so that an aircraft on the normal glideslope to the aircraft carrier 1 passes out of the coverage of the landing aid system when the aircraft is at 0.5 nautical miles (nm) (plus or minus 0.1 nm) from the normal touch-down point on the landing deck of the aircraft carrier 1. Furthermore, the vertical extent of the corridors is in the range of 4.0 to 5.0 degrees, and oriented such that an aircraft on a normal glideslope passes through the upper edge of the corridor coverage at a predetermined distance such as 0.5 nm from the touch down zone. The exact distance can be varied as necessary for any particular application, although it is expected that this distance will typically be in the range of 0.4 to 0.6 nm. The corridor design described above is the preferred configuration for an aircraft carrier-based laser

visual landing aid for azimuthal guidance and is one embodiment of this invention.

Land-based applications of laser visual landing aids can be very beneficial for parallel runway separation, low cost replacements for normal approach lighting and emergency airfield lighting. Land-based applications have slightly different requirements than sea-based applications, and a different corridor design is necessary to optimize land-based system performance. Figure 2 is a schematic diagram of a laser visual landing aid corridor design for azimuthal guidance for an approach to a land-based landing field. In the case of the land-based centerline guidance systems for use with a land-based runway 2 the azimuthal corridor widths are as follows: the centerline amber (first) corridor 20 is 0.5 degree wide, plus or minus 0.1 degree, the steady red and green (second and third) corridors 21 and 22 are 0.8 degree wide plus or minus 0.1 degree, the slowly flashing red and green (fourth and fifth) corridors 23 and 24 are 1.5 degrees wide, plus or minus 0.15 degree, and the rapidly flashing red and green (sixth and seventh) corridors 26 and 27 are 2.25 degrees wide in azimuth, plus or minus 0.225 degree. In each case the corridors 21-27 are 4 to 5 degrees high (in elevation). Although individual installation may require slight variations, the lowest portions of the corridors 21-27 are between 0 and 1 degrees above the runway. Land-based applications of laser visual landing aids can be enhanced by using two or more complete visual aid landing systems (of the sort just described) disposed along the extended centerline or glideslope plane which is defined relative to the runway 2. This produces a distinctive visual appearance which improves pilot recognition of the landing area. This corridor design, together with the use of one or more systems for a distinctive display in a land-based application, is a second embodiment of the invention.

Helicopter operations in land- and sea-based environments will also find the system a valuable enhancement for safety. Figure 3 is a schematic diagram of a laser visual landing aid corridor design for azimuth guidance for an approach to a helicopter landing zone (or pad). Due to the unique character of helicopters and helicopter landing zones 2, a different corridor

design is used for such applications. In such cases, the central  
amber (first) corridor 30 is slightly wider than for carrier- or  
land-based fixed wing aircraft facilities. For helicopter  
landing zone landing aid system, the central corridor 30 is 0.6  
5 degree in width, plus or minus 0.1 degree. The steady red and  
green (second and third) corridors 31 and 32 remain at 0.8  
degree plus or minus 0.1 degree, and the slowly flashing red and  
green (fourth and fifth) corridors 33 and 34 are widened to 0.4  
degree, plus or minus 0.04 degree. There are no rapidly flashing  
10 corridors in this design. Vertical height of each of the  
corridors 30-34 is in the range of 4 to 5 degrees. This corridor  
design, specific to helicopter applications is a third  
embodiment of this invention.

Another aspect of this invention is a change in the design  
15 of the flashing corridors. In the current art the flashing  
corridors flash in a standard repetitious on/off fashion. The  
simple rhythm of the standard flash is designed to alert the  
pilot to deviations well off the desired centerline or  
glideslope. In practice this simple flashing scheme can be  
20 confused with flashing beacon lights aboard other aircraft or on  
the ground. This confusion can reduce the utility of the current  
art. In this invention the design of the flashing corridor is  
changed and a rhythm composed of a short pulse followed by a  
long pulse is introduced. Figure 4 is a schematic diagram  
25 showing the temporal pattern of the dot-dash flash rate for both  
the slowly flashing and rapidly flashing corridors. The pattern  
of repeating short and long pulses allows the pilot to  
distinguish the laser system from other lights, particularly at  
long range. In this design the "dot" portion of the pulse is  
30 approximately 12.5% of the total cycle, the space between the  
dot and the dash is approximately 25% of the cycle, the dash is  
approximately 37.5% of the cycle, and the following space before  
the dot is repeated is approximately 25% of the cycle. This  
allows the dash period to be approximately three times as long  
35 as the dot period. These proportions are the same for the slow  
and rapid flash rates both of which use the dot/dash scheme. For  
the slowly flashing signal this entire pattern is repeated 35 to  
40 times per minute. For the rapidly flashing signal this entire  
pattern is repeated 60 to 70 times per minute.

An additional aspect of this invention is a modification to the optical design of the visual landing aid system. Figure 5 is a schematic diagram of the optical beam train for a single laser corridor of the visual landing aid system as described above. In the current art, light from a light source such as a laser 50 scattered off of the collimating objective lens 54 at the exit of the beam train can sometimes be seen by pilots. This scattered light is not part of the signal and can cause distractions and confusion on the part of the pilot. This invention includes a system of baffles integrated into the weather cover which prevent most of the scattered light from radiating out into the approach area effectively solving this. The baffle system is composed of a series of barriers which are located between the exit apertures of the various laser beams and are parallel to their direction of propagation. These prevent scattered light from the objective lens 54 from propagating into the adjacent corridor. In addition, on the front of a weather shield is a barrier plate 51 which is perpendicular to the direction of laser beam propagation. Rectangular holes are cut in the barrier plate 51. These holes are designed to allow the direct beam through while blocking off-axis scatter. Using this technique the problem associated with scattered light is effectively suppressed, with an additional benefit of enhanced weather protection for the objective lens 54.

Further improvements provide for methods and means to improve the manufacturability and maintainability of the laser visual landing aid of the present invention. In particular, during the fabrication of the landing aid, relatively critical co-alignments of the corridors are necessary. Current art provides for laser light from either the laser or a fiber optic (which will be understood by those skilled in the art of lasers and fiber optics) to be directed through a beam-expanding lens (usually a microscope objective, such as shown with reference number 53 in Figure 5) and then subsequently shaped by an optional cylindrical lens 56, objective lens 54 and corridor definition mask 57. In principle, the necessary co-alignment must be made through the precise location of each of these components. This method requires a fair amount of effort, making

fabrication an expensive process. In this invention an additional optical element 52 is added to the beam train to allow for ease of corridor alignment. Typically this element will be an optical flat but in some cases it can be a lens. The optical element 52 is placed near the focus of the beam expander telescope (including the microscope objective 53 and the objective lens 54) or in any location where the beam is relatively small. By tilting the optical element 52 it is then possible to steer the direction of propagation of the corridor. This steerage occurs due to the apparent shift of the position of the beam focus. In this invention each one of the optical beam trains (one for each corridor) has such an optical element 52. By manipulating the direction of propagation of each corridor relative to the others via these tiltable optical elements 52 it is possible to fully align the system with only modest positional requirement for the optical elements within the beam train. This will reduce the cost in effort required to manufacture such a system.

Eventually the laser light sources within the landing aid will require replacement due to damage or age. In the current art each laser is mounted as an individual and each replacement laser must be manually adjusted once the laser is placed in the laser visual landing aid. This requires a trained technician at the site of the replacement. To improve the practicality and reduce the expense of in-field replacements a different approach is required. In this invention the laser is placed into a cassette 60 which can be aligned when manufactured. Figure 6 is a schematic diagram of the laser mounting cassette 60 of the inventive system, showing the precision expanding latching pins 62, and the tangs 63 and clevis 61. Exact placement of the laser cassette 60 within the device is accomplished using a series of pins and brackets. In particular to assure proper alignment of the cassette, at three different positions along the base of the cassette 60 are located the clevises 61 with approximately .25 inch diameter holes which are oriented along the axis of the laser beam propagation. These holes are designed to fit the precision pin 62, or an expanding pin of the Carr Lane type CL-4-EXP-1.00. These expanding pins allow for precision location when set, with a reduced diameter for easy insertion and removal.

when released. On the base plate 65 of the landing aid device are three upright tangs 63 which also receive the precision pins 62. These tangs 63 fit within the clevises so that when the pins 62 are inserted the laser cassette 60 is held firmly against the  
5 base 65. In particular to assure an accurate placement of the cassette 60 without over-constraining and distorting it, two of these tangs 63 located on the same side of the cassette have circular holes of the same diameter of the hole in the clevis 61. These tangs 63 are placed on the base 65 so that the holes  
10 are lined up along the direction of propagation of the laser beam. The third tang 64, located on the opposite side of the cassette 60, has a slotted shaped hole which locates the pin vertically but allows motion side-to-side to prevent over-constraints. By fabricating the device in this fashion it will  
15 be possible for easy field replacement of laser cassette 60 reducing the cost and increasing the utility of laser visual landing aid.

It will be appreciated by those skilled in the art that the systems described in the foregoing could be powered by any  
20 appropriate source of electrical energy. Because of the high electrical efficiency of the systems described previously due to their efficient corridor design, the corresponding low power requirements will allow the systems to be powered by solar cell charged batteries in accordance with conventional practice. This  
25 is not possible with ordinary approach lighting systems.

While the foregoing is a detailed description of the preferred embodiment of the invention, there are many alternative embodiments of the invention that would occur to those skilled in the art and which are within the scope of the  
30 present invention. Accordingly, the present invention is limited only by the following claims.

Claims

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1. A visual aid for azimuthal guidance of landing aircraft,  
5 the aid defining landing corridors, including a central fan-  
shaped corridor continuously filled with a first color of light,  
second and third fan-shaped corridors adjacent the two fan-  
shaped surfaces of the central corridor, the second and third  
corridors being respectively continuously filled with second and  
10 third colors of light which differ from the first color of  
light, and fourth and fifth fan-shaped corridors respectively  
adjacent the two fan-shaped surfaces of the second and third  
corridors, the fourth and fifth corridors being respectively  
intermittently filled with the second and third colors of light  
15 at a first rate.

2. The visual aid of claim 1, wherein the width of the  
center corridor is in the range of 0.4 to 0.6 degrees, the  
widths of the second and third fan-shaped corridors are both in  
20 the range of 0.6 to 1.0 degrees, the widths of the fourth and  
fifth corridors are both in the range of 3.0 to 4.0 degrees.

3. The visual aid of claim 1, wherein the vertical extent  
of the center corridor, the second and third fan-shaped  
25 corridors, and the fourth and fifth corridors are in the range  
of 4.0 to 5.0 degrees, and the lower edges of the corridors are  
in the range of 0 to 1.0 degrees above the horizon.

4. A laser visual landing aid system comprising at least  
30 two independent systems as described in claim 1, wherein said  
systems are colinearly located along a glideslope or centerline  
plane and aligned in the same direction.

5. A laser visual landing aid system as described in claim  
35 1, further comprising an electrical power supply system  
including solar cell charged batteries.

6. A visual aid for azimuthal guidance of landing aircraft,  
the aid defining landing corridors, including a central fan-





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shaped corridor continuously filled with a first color of light, second and third fan-shaped corridors adjacent the two fan-shaped surfaces of the central corridor, the second and third corridors being respectively continuously filled with second and third colors of light which differ from the first color of light, fourth and fifth fan-shaped corridors respectively adjacent the two fan-shaped surfaces of the second and third corridors, the fourth and fifth corridors being respectively intermittently filled with the second and third colors of light at a first rate, and sixth and seventh fan-shaped corridors respectively adjacent the two fan-shaped surfaces of the fourth and fifth corridors, the sixth and seventh corridors being respectively intermittently filled with the second and third colors of light at a second rate that is different from the first rate.

7. The visual aid of claim 6, wherein the second rate is faster than the first rate.

8. A laser visual landing aid system as described in claim 6, further comprising an electrical power supply system including solar cell charged batteries.

9. The visual aid of claim 6, wherein the vertical extent of the center corridor, the second and third fan-shaped corridors, and the fourth and fifth corridors are in the range of 4.0 to 5.0 degrees, and the lower edges of the corridors are in the range of 0 to 1.0 degrees above the horizon.

10. The visual aid of claim 6, wherein the width of the center fan-shaped corridor between its two surfaces is less than the widths of the other corridors.

11. The visual aid of claim 10, wherein the widths of the second and third fan-shaped corridors are substantially equal, the widths of the fourth and fifth fan-shaped corridors are substantially equal, and the widths of the sixth and seventh fan-shaped corridors are substantially equal.





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12. The visual aid of claim 10, wherein the widths of the fourth and fifth fan-shaped corridors are respectively greater than the widths of the second and third corridors and the widths of the sixth and seventh fan-shaped corridors are respectively greater than the widths of the fourth and fifth corridors.

13. The visual aid of claim 6, wherein the width of the center corridor is approximately 0.5 degrees, the widths of the second and third fan-shaped corridors are both approximately 0.8 degrees, the widths of the fourth and fifth corridors are both approximately 3.0 degrees and the widths of the sixth and seventh corridors are both approximately 6.0 degrees.

14. The visual aid of claim 6, wherein the width of the center corridor is approximately 0.5 degrees, the widths of the second and third fan-shaped corridors are both approximately 0.8 degrees, the widths of the fourth and fifth corridors are both approximately 1.5 degrees and the widths of the sixth and seventh corridors are both approximately 2.25 degrees.

15. The visual aid of claim 6, wherein the upper edge of the vertical extent of each of the corridors is oriented such that an aircraft on a normal glideslope will pass from the area of coverage of the visual aid at a predetermined distance from a touchdown zone of a landing area.

16. The visual aid of claim 6, wherein the first rate is substantially 35 to 40 times per minute and the second rate is substantially 60 to 70 times per minute.

17. The visual aid of claim 16, wherein the light at the first rate and the light at the second rate follows a pattern comprising a short pulse of light followed by a longer pulse of light, these patterns being respectively repeated at the first and second rates.

18. A laser visual landing aid system comprising at least two independent systems as described in claim 6, wherein said





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systems are colinearly located along a glideslope or centerline plane and aligned in the same direction.

5 19. A laser visual landing aid for guidance of a landing aircraft, comprising an optical system having an exit objective lens with a series of baffles external to the exit objective lens to prevent the propagation of unwanted scattered light.

10 20. A laser visual landing aid for guidance of a landing aircraft, comprising an optical system to produce a plurality of corridors of light, the optical system including an internal tiltable optic for precise co-alignment of the corridors of light.

15 21. A laser visual landing aid for guidance of a landing aircraft, comprising a plurality of optical components the optical components including mechanical means to allow reproducible and easy field replacement of the optical components.

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22. A method for producing a visual aid for azimuthal guidance of landing aircraft, comprising the steps of:

a) providing a central fan-shaped corridor continuously filled with a first color of light;

25 b) providing second and third fan-shaped corridors adjacent the two fan-shaped surfaces of the central corridor, the second and third corridors being respectively continuously filled with second and third colors of light which differ from the first color of light;

30 c) providing fourth and fifth fan-shaped corridors respectively adjacent the two fan-shaped surfaces of the second and third corridors, the fourth and fifth corridors being respectively intermittently filled with the second and third colors of light at a first rate; and

35 d) providing sixth and seventh fan-shaped corridors respectively adjacent the two fan-shaped surfaces of the fourth and fifth corridors, the sixth and seventh corridors being respectively intermittently filled with the second and third





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colors of light at a second rate that is different from the first rate.

23. A method for producing a visual aid for guidance of  
5 landing aircraft, the aid defining landing corridors, comprising the steps of:

a) providing a central fan-shaped corridor continuously filled with a first color of light;

b) providing second and third fan-shaped corridors adjacent  
10 the two fan-shaped surfaces of the central corridor, the second and third corridors being respectively continuously filled with second and third colors of light which differ from the first color of light; and

c) providing fourth and fifth fan-shaped corridors  
15 respectively adjacent the two fan-shaped surfaces of the second and third corridors, the fourth and fifth corridors being respectively intermittently filled with the second and third colors of light at a first rate.

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