Operation of the Laser Centerline Localizer on the USS Constellation and Civilian Airports

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ABSTRACT

The Laser Centerline Localizer (LCL) uses a series of low power, but highly visible laser beams to illuminate approach corridors to provide a pilot on final approach to landing with precise centerline guidance. The first operational deployment of the LCL on the U.S.S. Constellation is discussed along with the results and conclusions from the flight operations to date. Civil applications of the LCL are described.

INTRODUCTION

The Laser Centerline Localizer is an extremely precise long range visual landing aid which was developed by Humbug Mountain Research Laboratories (HMRL) with the initial application for aircraft carriers. HMRL has taken Laser-based Visual Landing Aids (LVLA) from the conceptual phase through the development phase to the prototype phase. The two principles who initiated the LVLA in 1986 formed Laser Guidance in November 1993 to manufacture and sell these improved landing aids. Demonstrations of the LVLA to various Navy organizations and the FAA have been conducted with outstanding results. Pilot acceptance of these systems has been unanimously favorable. Field tests have shown that with the LCL pilots can consistently obtain proper line up at long range, starting from their very first approach.

In 1993, HMRL provided demonstrations of the LVLA to fleet pilots at training fields across the country. As a result the LCL was chosen as the most important safety item desired by the Landing Safety Officers (and thus the fleet). In 1994, Laser Guidance supported training of Air Wing CVW-2 and installation of the LCL on board the aircraft carrier U.S.S. Constellation (CV-64). This LCL was a modified commercial unit, a dual-use application. The most difficult task in all of aviation is landing on the deck of an aircraft carrier at night while at sea. The first application of the LVLA technology solved one aspect of this problem.

During an approach to landing, a modern aircraft carrier presents the pilot with a wide variety of visual cues. These include, but are not limited to, the apparent size and perspective of the carrier itself, the centerline and marginal lines which outline the landing area, and the Fresnel Lens Optical Landing System. Due to high approach speeds, high momentum, and relatively slow control response of jet aircraft in the landing configuration, a small initial drift from the centerline can become a serious and potentially dangerous misalignment to the arresting cables and landing area. This problem is accentuated at night when many of the normal visual cues are absent or impaired. The LCL has been developed to augment the present visible landing system to enhance the visual cues available to the pilot. The LCL provides a precise definition of the centerline and provides information as to the degree of right or left deviation from the centerline. To be of real use to the pilot such additional information must be easy to interpret as well as precise; the LCL satisfies both of these criteria.

The use of laser-based visual landing aids has significant advantages. The primary advantage lies in the use of lasers for the illuminating source. These advantages come from two properties of the laser: spatial coherence and color purity. The coherent nature of the laser causes the light to appear to come from a single point source rather than the distributed source common to incandescent florescent, or arc lights. Thus, it is possible to define the edge of a particular corridor as sharply as the limits of diffraction will allow. In practice, the ‘fuzziness’ of the corridor edge is only about 1 inch in width at the range of one mile. From the pilots perspective, this means that the transition from corridor to corridor will be abrupt and clean. This makes transitions between corridors readily apparent and reduces recognition time. Similarly, the color purity keeps the color of the corridors well defined, even in the presence of atmosphere haze, once again reducing recognition time.

PRINCIPLES OF OPERATION

The LCL uses three fan shaped laser beams, red, yellow (amber), and green in color, as illustrated in Figure 1. The yellow Laser beam illuminates the central corridor, which lines up with the centerline of the runway and forms an extension of it. The red beam illuminates the side to pilot’s left, and the green laser illuminates the corridors to the other side. Due to the high degree of collimation possible with Lasers, the corridors are extremely well defined and can be easily tailored for optimal shape. The pilot approaching the runway

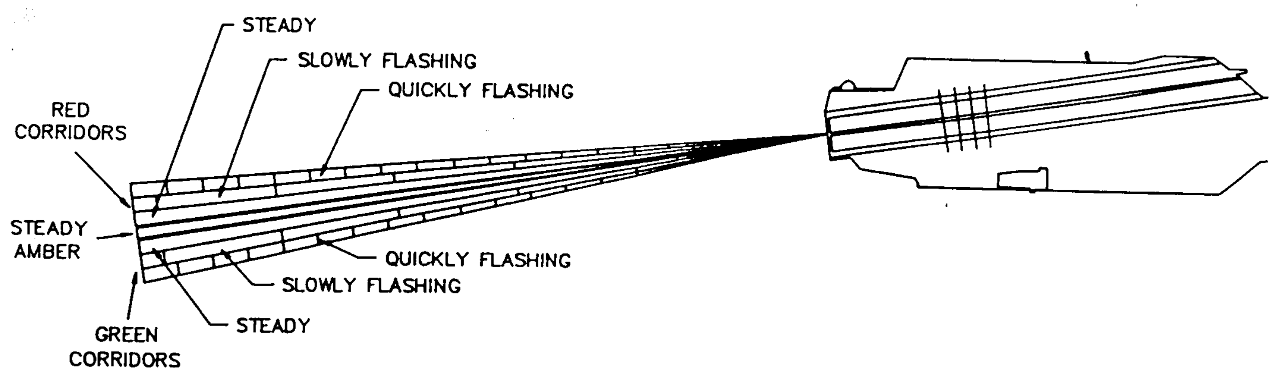

Figure 1: Schematic of an aircraft carrier flight deck and the corridors illuminated by the Laser Centerline Localizer. A pilot flying down the central corridor will see a steady amber (yellow) light. When left (towards the port side) of the centerline the pilot will see red signals only, either steady or flashing depending upon how far the aircraft is off course. When right (towards starboard) of the centerline similar green signals will be visible.

would see a yellow (amber) light when on course, a red light when left of the centerline, and a green light when to the right. To provide the pilot with the degree of deviation, the off course signal is modulated in intensity with a frequency that varies depending on how far the pilot is off course. If slightly to the right or left of the well defined on course corridor, the pilot will see only a steady green or steady red light, respectively. If the pilot is in a region further to the right or left of the centerline the red or green light will flash at a slow rate, and a further drift from the proper course will yield a signal which flashes at a higher rate. In this way, the pilot knows not only if he is on course or not but also to what degree and direction he is off course, so that proper correction can be made. The outer LCL corridors serve as turn indicators, an advantage not feasible with the currently implemented visual landing aids. On the base leg before the turn to final approach, the pilot initiates a turn when the rapidly flashing corridor is sighted. The boundary between the rapid and slowly flashing corridors provides an indication of approaching centerline and the pilot adjusts the rate of turn accordingly. The steady corridor alerts the pilot that the intercept is nearly complete, and the appearance of the yellow light shows that the intercept is complete.

Traditional visual landing aid presentations, such as the VASI and PAPI, require that the pilot perceive one or more lights in relation to other lights. Such perception requires spatial resolution of the presentation by the pilot. This means that the information being presented degrades with range and adverse weather. The main advantage of the LCL is that the pilot does not need to resolve a pictorial presentation in order to interpret his position with respect to the centerline; only perception of color and temporal frequency are required. Since the information presented by the LCL does not require optical resolution by the pilot the LCL signals would be functional in marginal weather so long as the color of the corridor light may be distinguished. Unlike conventional lighting, the color of laser light is monochromatic and does not change with fog or haze. Atmospheric scattering preferentially removes the blue part of the spectrum of conventional lighting so that its color changes with distance. This leads to increased difficulty of perception of the conventional displays.

On an aircraft carrier, the Laser Centerline Localizer is placed below the ramp at the stem of the carrier. The unit is stabilized to project corridors to form an extension of the deck centerline. In this position, the LCL is not obscured by men and machines on the flight deck and approaching aircraft will not normally obscure the beams from other aircraft following in the pattern. The LCL beams are baffled to disappear from the pilot's view at a range of 1/2 mile to eliminate any distraction from the normal visual cues.

The LCL corridors can be used to provide a tactical advantage not feasible with the currently implemented visual landing aids. The LCL provides signals for a night EMCON (no radio, no radar) approach. The pilot proceeds from marshal along a given vector which intercepts the extended deck centerline at an angle of 60 to 90. The pilot initiates a turn when the rapidly flashing corridor is sighted. The boundary between the rapid and slowly flashing corridors provides an indication of approaching centerline and the pilot adjusts the rate of turn accordingly. The steady corridor alerts the pilot that the intercept is nearly complete, and the appearance of the yellow light shows that the intercept is complete.

INSTALLATION ON USS CONSTELLATION

On Dec 22, 1993, Laser Guidance and its teammate, the Raytheon Co., were given approval to train Carrier Air Wing Two (CVW-2) in the use of the Laser Centerline Localizer (LCL) and install the LCL aboard the aircraft carrier USS Constellation, CV-64. This company funded effort represents the finite use of a long range precision visual line-up system in an operational carrier environment. The effort was divided into three phases, one of which is ongoing. These phases are training, installation, and deployment. The training and installation phases are complete and ran concurrently.

The training phase began on Feb 1, 1994 at NAS Whidby Island. The primary purpose of a total of three nights of flying was to provide initial training to VAQ-131, the CVW-2 Prowler squadron. Each pilot was required to attend a lecture on the layout, principle of operation and proper use of the system. In addition, the pilots were to fly the system during two sessions before flying it at the boat. Laser Guidance representative Dr. David Shemwell delivered the required lecture and provided set-up and technical support for the flight portion. Following the Whidby session, the LCL was transported to NAS Lemoore. At Lemoore CVW-2's F/A-18 pilots received trained in the use of the LCL. VFA-137, VFA-151, and VMFA-323 were the squadrons involved. The Lemoore squadron received their briefings in person, the El Toro squadron were shown a video tape of the Whidby briefing. The flying sessions occurred on the nights of Feb 7-10, 1994. Following Lemoore the LCL was transported to San Clemente Island to train the remaining squadrons (VS-38, VF-2, VAW-118) during the evenings of Feb 14-18, 1994. These squadrons all received their lectures in person during two sessions, one at NAS Miramar, and one at NAS North Island.

Concurrent with the training sessions was the installation of the LCL system aboard CV-64. Starting on Dec. 2, 1993 Laser Guidance personnel began their interface with CV-64 with a site visit. Numerous other site visits followed in order to select a mounting spot, determine cable runs, and design the mechanical interfaces. During this phase the EMR Division and in particular the staff which maintains the SPN-41/SPN-46 radar were our primary points of contact and an immense help. Based on the physical parameters, Laser Guidance designed and built a welded steel platform which allows the LCL to be supported in a cantilevered fashion from the small weather deck on the 01 level. This platform was designed to allow the LCL to be placed as close to the centerline as possible without modification to the dropline. In this position the LCL is approximately 3 feet off the centerline. It was determined that this offset would not be significant. The platform is bolted to pads that were welded to the dock and is also supported by a separate foot under the cantilevered section.

On Feb 17, 1994 this platform was hoisted into position aboard CV-64, and bolted to the deck. The LCL stabilization platform was hoisted to the 01 level on the same day, but it was left at dock level to await the integration of the LCL optical head functional checks of the control panel and final wiring. At about the same time a cable was run from the LCL to the LSO platform by ships personnel. On Feb 18, 1994 the LCL optical head was integrated and functional checks were successfully performed. On Feb 21, 1994 the LCL was lifted into position on the platform and preliminary alignment was performed. Alignment was effected by using an alignment Laser to provide a displaced extension of the landing area centerline. This extended centerline was transferred to a separate alignment Laser which was mounted atop the SPN-41 dome. From this vantage point the second alignment laser could be used to extend the centerline down at an angle. This downwardly angled centerline extension was then used to align the LCL. On Feb 22, 1994 CV-64 set sail.

During the first day at sea there were no flight operations. This time was used to perform verification of the basic function of stabilization and control. All functional checks were nominal. Following this were several days of CQ (carrier qualification for the pilots) during which, by previous agreement, the system was secured. On Feb 25 and 26 alignment checks were performed using helicopters from HS-2, the indigenous helicopter squadron. In this evolution the pilots were instructed to call the corridor transition, and these calls were noted on the PLAT camera display. As a result of these two nights minor alignment changes were made and on Feb 27, 1994 the system was used operationally for the first time.

The LCL was used on all subsequent flying nights for this at sea period (TSTA-1). During this time there was essentially no moon (it rose after the last recovery). The weather varied from clear to a minimum of about 800 broken, with 1200-1500 broken to overcast as typical. After each evening's flying Laser Guidance representatives talked to as many pilots as practical. In addition Laser Guidance personnel (either Dr. Shemwell or Dr. Vetter) continue in their training role by discussing proper techniques to maximize the effectiveness of the system. The system was used over the course of the next two weeks. A questionnaire was circulated to all flight crew members to be filled out at the end of this at sea period. Here we will summarized the information we obtained via pilot interviews, as a result of observing the night recoveries, and from the survey.

Pilots adapted to the system fairly quickly, though it varied from pilot to pilot and was somewhat aircraft related. It took the average pilot about 2 approaches to get the hang of it. Initially there were some concerns expressed about the width of the central corridor, but this concern essentially disappeared after the first round of approaches. By the end of the at sea period the LSO's and most pilots felt that enlarging the central corridor would be a mistake. Once pilots learn to use the increased sensitivity they come to prefer it.

During this at sea period, the LCL was stabilized in pitch and roll, but intentionally not in yaw. The weather and sea conditions were able to provide a moderate amount of deck motion. This motion did not seem to cause any real problems. Indeed there is a major benefit to not having yaw compensation. The first advantage is that the LCL always tells the pilot the orientation of the deck; it can never be wrong and therefore has a high value of "truth" (as opposed to stabilized which can malfunction, and even when working properly can get itself into a condition where it does not agree with the deck). In addition, the LCL reacts immediately to turns and allows a properly trained pilot to anticipate movement of the instruments.

In the area of pilot acceptance, the initial results are excellent. Pilots were able to use the system effectively and many developed a very high degree of trust in the system in a short period of time. This acceptance was possibly accelerated by the frequency of faults in the radar based system which frequently left pilots with only the LCL for guidance (other than surveillance radar). The LCL was often (according to pilot interviews) able to significantly improve pilots spatial awareness and reduce uncertainty.

In summary, the initial deployment of the LCL has been extremely successful. It has conclusively demonstrated that the LCL can be effectively integrated into aircraft carrier flight operations quickly and with a minimum of fuss. During this first at sea period tactical cyclic flight operations where conducted from the very first day of LCL use.

RESULTS FROM THE USS CONSTELLATION

During May and June 1994, CV-64 and CVW-2 deployed for a two month at sea period which was a combination of Comtuex and RimPac mini-cruise. This period was the first extended deployment of the LCL and the first true blue water operational experience for the system. There were no changes in equipment configuration for this deployment. At the end of the deployment CVW-2 pilots where asked to fill out a survey form which was similar to the full survey. In this case we were primarily interested in seeing the effect of the learning curve. We received 110 responses representing every squadron and nearly every pilot on the ship.

"How was the sensitivity of the system?" By the end of RimPac the pilots were much more experienced with the system and this greater familiarity was reflected in the results of this question. The answers are graded from 1 to 9 with 5 being "about right", 1 being "too sensitive", and 9 being :"not sensitive enough". In this survey 68% responded that the system was about right and 22% chose the most minor of the too sensitive category (response 4). This compares with 43% about right 31% a little too sensitive (response 4), and 23% response 3, number after TSTA-1. In other words more than two thirds of the pilots currently feel the sensitivity is correct vs less than half after TSTA-1. Furthermore 90% of all current responses are in category 5 or 4 verses 74% after TSTA-1. In addition many of the pilots who feel it is about right express a strong desire to not reduce the sensitivity at all.

"Were you able to adjust your scan to use the LCL or did you tend to fixate?" Once again the teaming curve shows positive improvement in this category. It is not as pronounced as in the previous question since most pilot felt it had no effect on their scan even after TSTA-1. At the end of RunPac there is a noticeable reduction in the percentage of pilots who felt their scan was adversely affected, with a corresponding increase in the number of pilots who felt their scan was positively affected.

"How easy was it to distinguish the flashing corridors from the other aircraft beacons?" Once again experience has lead to modest improvements in this category. At the end of RimPac no pilots are checking the extremely difficult category while nearly 50% are checking the "very apparent" category.

"How much did ship motion and heading changes affect your use of the LCL?" This question is particular interesting since for this installation the LCL is fixed to the landing area centerline (i.e. no yaw stabilization has been implemented). Very few pilots found this condition detrimental (only 12% in categories 2,3 and 4), and 35% felt ship's motion had no effect. More than half of the pilots found it helpful to varying degrees.

The deployment of the Laser Centerline Localizer aboard CV-64 has yielded a great deal of valuable information. The following have been demonstrated:

* An operational airwing can be trained to use the LCL in the FCLP (field carrier landing practice) environment relatively quickly (i.e. a briefing and one or two flight periods);
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* The LCL can be easily integrated into the normal CV night operations;
* The LCL has demonstrated effective precision centerline guidance at ranges beyond 10 nautical miles with reports of use beyond 15 nautical miles;
* Squadron and Airwing LSOs report noticeably improved flight performance for pilots using the LCL; and

The LCL has excellent pilot acceptance.

Other Observations:

* There is no need for extensive intensity control; four postionswere sufficient. During the entire time to date the system has never been adjusted in intensity;
* The cut-off range of 1/2 mile was found to be at the right range by the vast majority of pilots and acceptable to all; and
* Yaw stabilization is not necessary. A short first constant yaw stabilization system would probably improve performance in heavy seas, but if not done right it will hurt the system. Indeed even if a yaw stabilization system is implemented it might be best to cage it (turn it off) when the seas are not heavy.

CIVILIAN USES

The primary benefit of the Laser Centerline Localizer to the user is improved safety on the most dangerous part of flight, the approach to landing. Pilots have vastly improved approach performance; their approaches are stabilized much farther out and the heads up nature of the LCL facilitates transition to normal cues. Avoided mishaps and lives saved are difficult to quantify. Therefore, the prime benefit to the civilian sector is improved capability at night and in marginal weather. It is important to note that the aircraft needs no special equipment of its own to use the LCL. Virtually any aircraft can use the system successfully.

Approach lighting systems which are currently used at airports are composed of a very large number of high intensity incandescent lights which extend out to as far as 3000 ft. from the approach end of the runway, often well beyond the physical boundaries of the airport. The cost of installation of one of these systems is very high and uses a large amount of land. The LCL can be installed instead of one of the approach lighting systems for much reduced costs. In addition, the LCL, which uses only 140 W, has very low operating costs compared to the approach lighting systems, while providing significantly improved long range visual guidance. Maintenance costs are extremely high for other approach lighting systems due to vandalism of lights and stands which are located beyond the airport boundary or are visible targets. In comparisons the LCL has no exposure to vandalism as it is contained in a single box which is shielded from view from outside the airport property. Because of the very low power consumption and very small amount of light projected into the approach corridor, the LCL is both environmentally friendly and a very good neighbor.

When located at the approach end of a runway, the LCL not only provides precision long range line-up guidance, but also serves as an approach indicator due to the geometrical relationship with the runway lights. One main advantage of the LCL is that the pilot does not need to resolve a pictorial presentation in order to interpret the aircraft's position with respect to the centerline; only perception of color and temporal frequency are required. Since the information provided by the LCL does not require optical resolution by the pilot the signals would be functional in marginal weather so long as the color of the corridor light may be distinguished. In this case, the highly directional lasers will not cause glare and wash-out of the other lights.

The LCL can provide a significant improvement in safety at airports where the terrain does not allow straight in approaches, such as at Juneau, Alaska. At such airports the LCL can be used to delineate the proper approach to the airport. The pilot would have a positive visual indication during the approach to the airport, improving pilot confidence and vastly reducing the chance that the aircraft will stray into dangerous areas. When used in conjunction with nondirectional beacons (NDB) or Localizer Directions Aids (LDA), the LCL will vastly improve the transition from instruments to the visual environment with concomitant improvement in safety.

The LCL can be used to improve positive separation of aircraft using parallel runways. If the runways have LCL's for approach lighting then the pilot will be certain of being on the proper extension of the assigned runway by maintaining an amber centerline signal at that runway. The parallel runways would show either a red or green signal depending on being right or left of the runway to which the pilot is lined up. This would be extremely valuable at airports such as Los Angeles International (LAX) where there are 4 parallel runways or Seattle-Tacoma Airport (SEA) where the parallel runway is not served by an ILS. The LCL would go a long ways towards solving the problem of aircraft incursions into other aircraft's assigned space during parallel approaches.

Under marginal conditions, the LCL can be utilized to recover VFR (visual flight rules) pilots. This is a potentially dangerous situation when an aircraft without instruments or a pilot without instruments training gets caught flying when the weather turns marginal. The aircraft needs to be brought down in the safest mode possible. With the LCL, the pilot is able to acquire guidance to line-up with the runway, before being able to see the runway, or other visual cues. By following the LCL signals, the pilot is ensured to be lined-up when positive visual contact is made with the landing zone.

Because of the small size and weight and very low power requirement, the LCL is part of a portable landing field system for emergency use at airports or on roadways. The dual-use LCL which is on CV-64 weighs 132 lbs, operates from a single 12 VDC battery, and can be set up on a runway or roadway in under 10 minutes. A much smaller and lighter LCL has been developed as part of a portable landing field. This unit is entirely self-contained, requiring no outside power, making it ideal for civil disaster relief operations. The battery can be solar charged during the daytime for extended remote operations.

There are many other potential civilian applications such as shipping lanes and harbor navigation, helicopter landing pads (particularly on oil drilling platforms), and docking. Because of its small size and light weight the LCL can be placed on a rotating platform, similar to that used for stabilization on CV-64, and aimed downwind so that helicopters can always approach in an upwind direction.

CONCLUSIONS

The Laser Centerline Localizer (LCL) has demonstrated to be a highly valuable landing aid for carrier flight operations. The LCL provides direct visual signals to the pilot that indicate a positive on centerline signal as well as the direction and degree of deviation from the proper approach. By using this system, the pilot has precision visual guidance at extended distances.

A LCL has been successfully installed and deployed on the aircraft carrier USS Constellation. An operational airwing can be trained to use the LCL in the FCLP environment with a briefing and one or two flight periods. The LCL can be easily integrated into the normal CV night operations. The LCL has demonstrated effective precision centerline guidance at ranges beyond 10 nautical miles with reports of use beyond 15 nautical miles. Squadron and Airwing LSO report noticeably improved flight performance for pilots using the LCL. LCL has excellent pilot acceptance. There is no need for extensive intensity control. There is no need to change the cut-off range from 1/2 mile. Yaw stabilization is not necessary or desirable.

The LCL is extremely useful for civil applications. The LCL provides definitive traffic separation for parallel runways. The LCL is extremely beneficial and safety enhancing at airports that have no good visual access at night due to terrain. Helicopter landing pads, particularly on oil platforms, greatly benefit from the LCL. Because of its small size, portability, and low power consumption, the LCL is ideal for civil disaster relief operations.