A SIMULATOR EVALUATION OF A RATE-ENHANCED INSTRUMENT LANDING SYSTEM DISPLAY

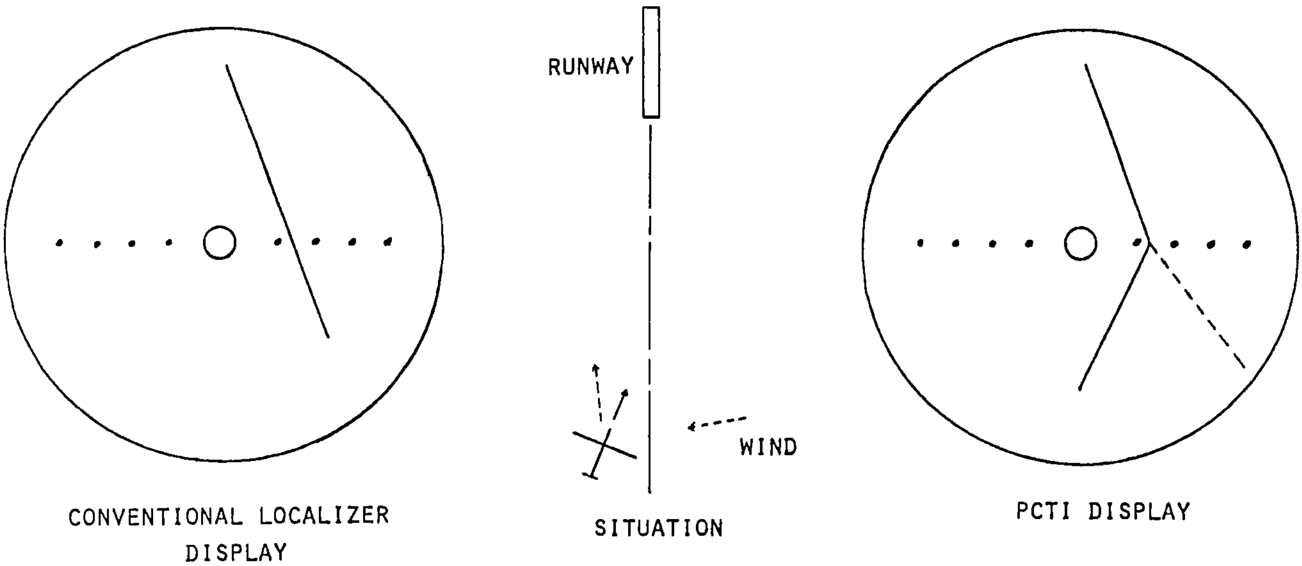
David A. Hinton
NASA Langley Research Center

ABSTRACT

A piloted simulation study was conducted to evaluate the effect on instrument landing system tracking performance of integrating localizer error rate information with the raw localizer error display. The resulting display was named the pseudo command tracking indicator (PCTI) because it provides an indication of any changes of heading required to track the localizer. Eight instrument-rated pilots each flew five instrument approaches with the PCTI and five instrument approaches with a conventional course deviation indicator. The results show good overall pilot acceptance of the PCTI and a significant reduction in localizer tracking error.

PSEUDO COMMAND TRACKING INDICATOR (PCTI)

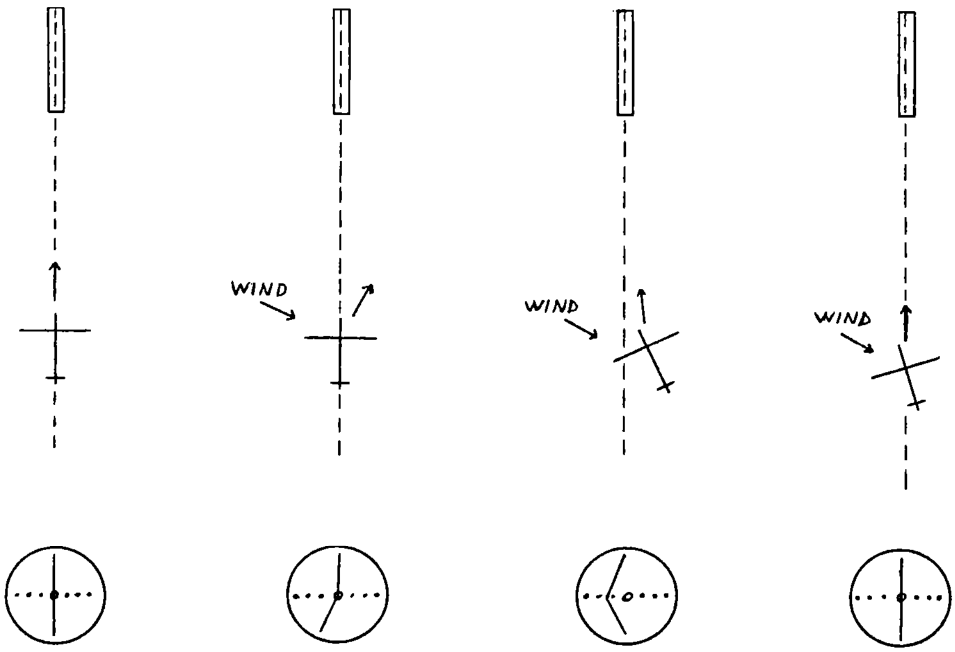
This figure compares the PCTI presentation and the conventional CDI presentation for two different flight situations. The PCTI consists of two needles joined at the horizontal centerline of the instrument. The upper needle presents the same raw localizer error information as is presented on the conventional display. The lower needle pivots from the upper needle and indicates localizer error rate. The PCTI in this figure depicts two situations. The airplane between the two displays is to the left of centerline and with no wind is returning to centerline (see solid flight path arrow). With a wind (see dashed wind vector arrow) the airplane is tracking away from centerline (dashed flight path arrow). The solid localizer error rate needle depicts the first situation. If the pilot turns the airplane to keep the tip of the rate needle centered, the result will be an asymptotic return to the centerline. The second situation is depicted by the dashed rate needle. The rate needle is deflected more than the localizer needle, indicating increasing error. If the localizer error rate were zero, then the two needles would form a straight line.



- DISPLAY LOCALIZER ERROR RATE ALONG WITH LOCALIZER ERROR
- PROVIDE TURN COMMANDS BY INTEGRATING THE TWO INDICATIONS
- "ON COURSE" INDICATION IS INDEPENDENT OF RUNWAY HEADING OR WIND CONDITION
- PROVIDES PILOT WITH LEAD INFORMATION

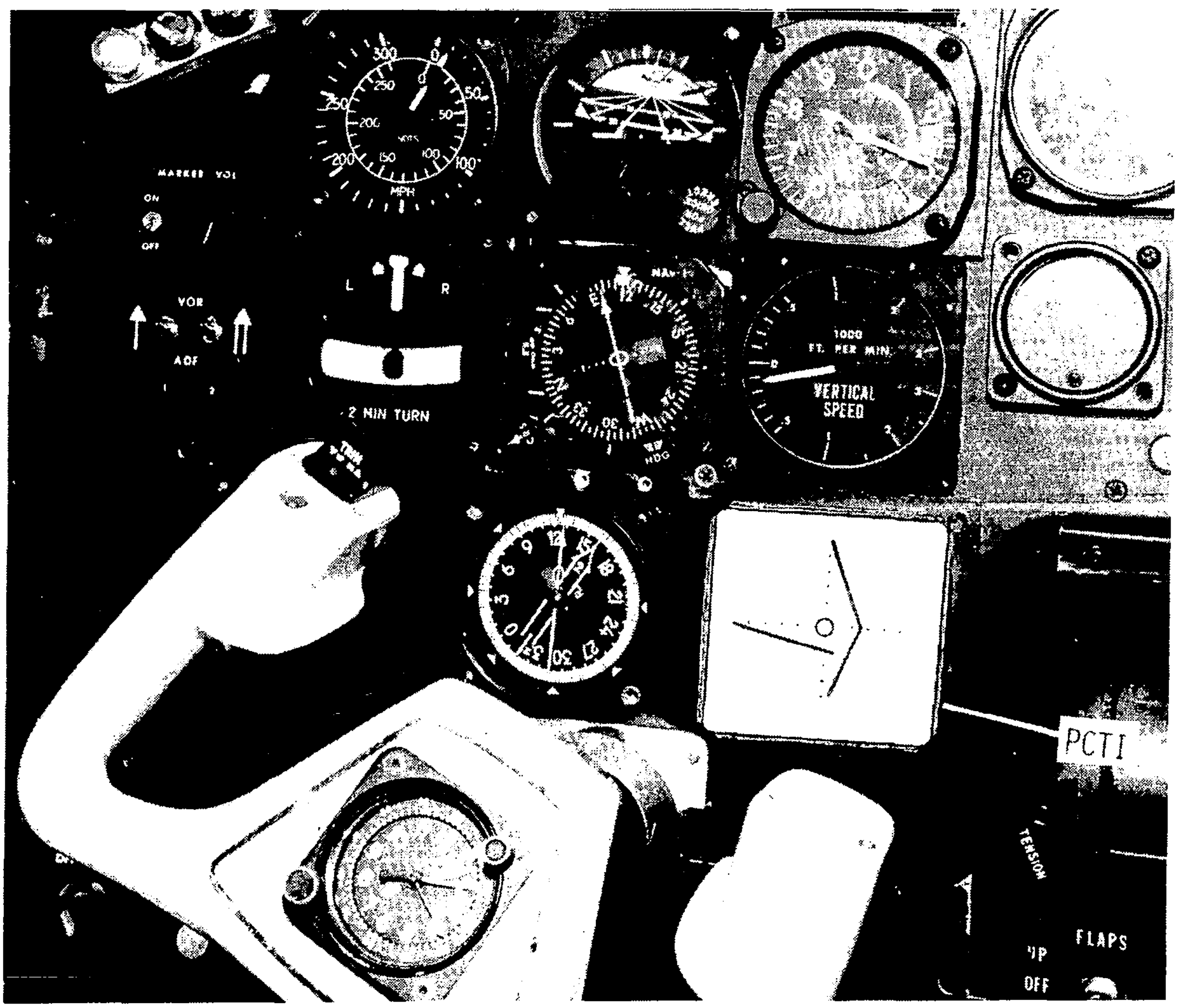
PCTI IN FOUR SITUATIONS

The diagram below shows an airplane in four situations and the corresponding PCTI displays. In the left-most figure the airplane is stabilized on the localizer centerline. Both needles of the PCTI are centered. In the next figure the airplane has begun to drift off centerline because of a wind. The localizer needle is still centered but the rate needle is deflected to the left, telling the pilot to turn to the left. The third figure shows the airplane to the right of the centerline on a flight path returning to the centerline. The localizer needle is deflected to the left and the rate needle is deflected back towards the center to indicate decreasing error. In the final figure the airplane is stabilized on centerline with a heading that compensates for the wind. Both PCTI needles are centered.



DISPLAY IMPLEMENTATION

The PCTI display was implemented in the NASA LaRC General Aviation (GA) Simulator. A 5-inch diagonal monochromatic CRT displayed the PCTI and CDI presentations. The CRT was located immediately to the right of the primary flight instruments in a typical GA instrument panel CDI location. The CRT presentation was chosen for the speed and ease of display implementation and does not imply that a CRT is necessary for a PCTI. Switching between CDI and PCTI presentation was accomplished by driving both needles as one needle with localizer error information when the CDI was desired. A conventional glideslope needle was also drawn on the CRT for the study.



TEST SUBJECTS AND DATA RUNS

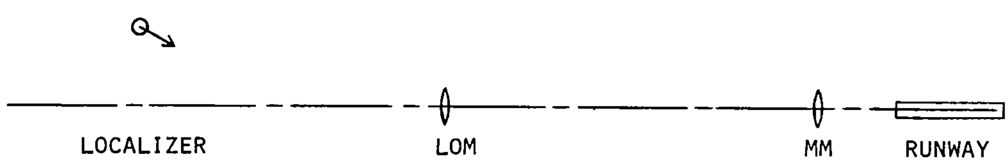
Data were collected from eight pilots. All of the pilots were instrument rated and their experience ranged from 250 hours to 6000 hours. Each of the pilots was given an explanation of the display and simulation task and was required to fly four practice approaches. More practice was allowed if requested.

Each pilot flew five data runs with the PCTI and five data runs with a conventional CDI. Since the run conditions were identical for each run, the runs were alternated between the CDI and PCTI to minimize learning effects.

- EIGHT SUBJECTS, ALL INSTRUMENT RATED, HOURS RANGE FROM 250 TO 6000
- EACH PILOT WAS GIVEN AN EXPLANATION OF DISPLAY AND RUN CONDITIONS AND FOUR PRACTICE RUNS
- DATA RUNS ALTERNATED BETWEEN CONVENTIONAL DISPLAY AND PCTI, FIVE RUNS WITH EACH DISPLAY PER PILOT

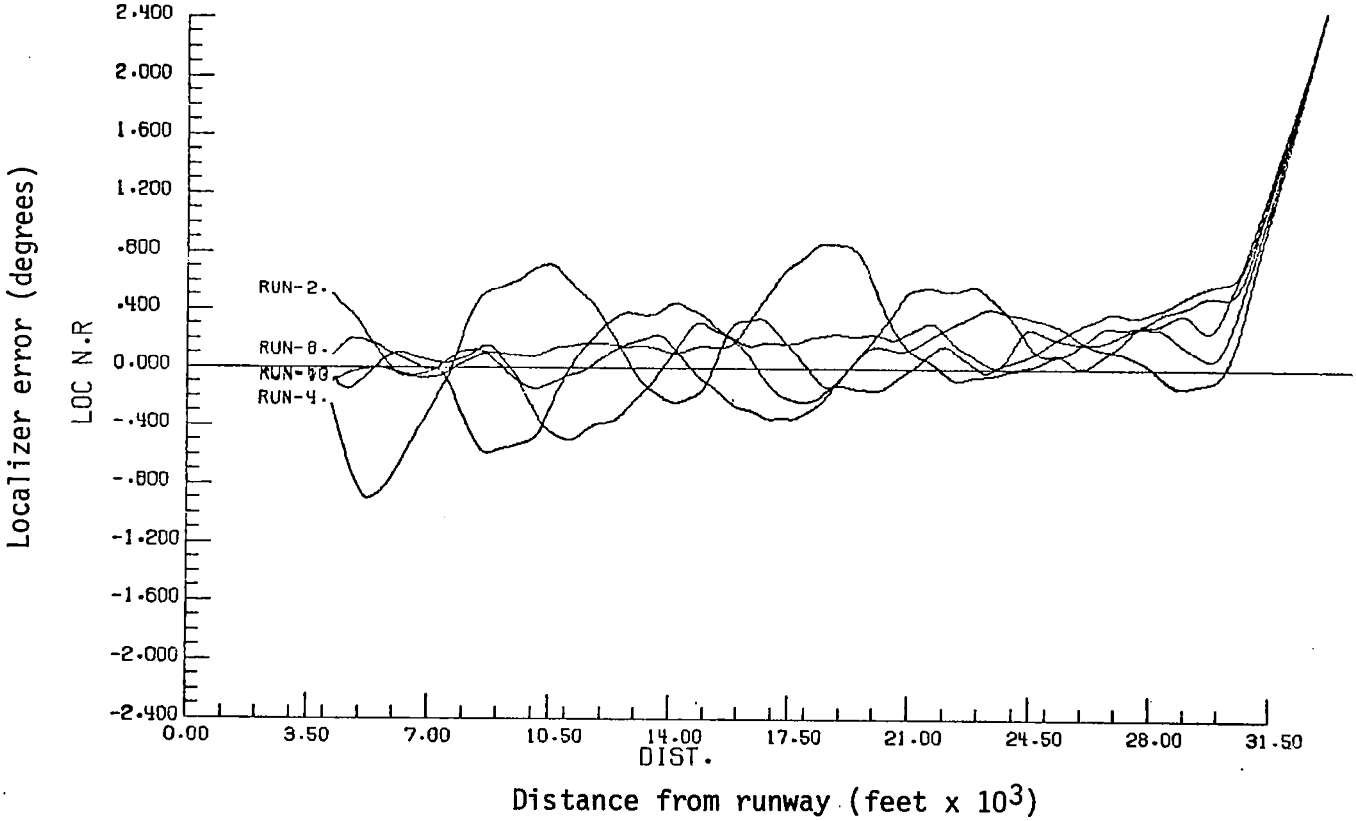
RUN CONDITIONS

Each data run began with the airplane 0.3 nautical miles left of the localizer centerline about 5.3 miles from the runway on a 30° intercept heading to the localizer as indicated by the circle and arrow in this figure. This situation resulted in a localizer intercept prior to reaching the outer marker or glideslope intercept. Identical weather conditions were used for each data run. At the initial altitude of 1000 feet above ground level a 24 knot wind from 12° right of localizer course was present. At the surface a 12 knot wind from 36° left of localizer course was present. Linear interpolation for both wind speed and direction was used at other altitudes. This provided a constantly changing wind as the airplane descended on the glideslope. Light turbulence was also present during each data run. Data runs were terminated with an automatic reset just prior to reaching decision height at the middle marker.



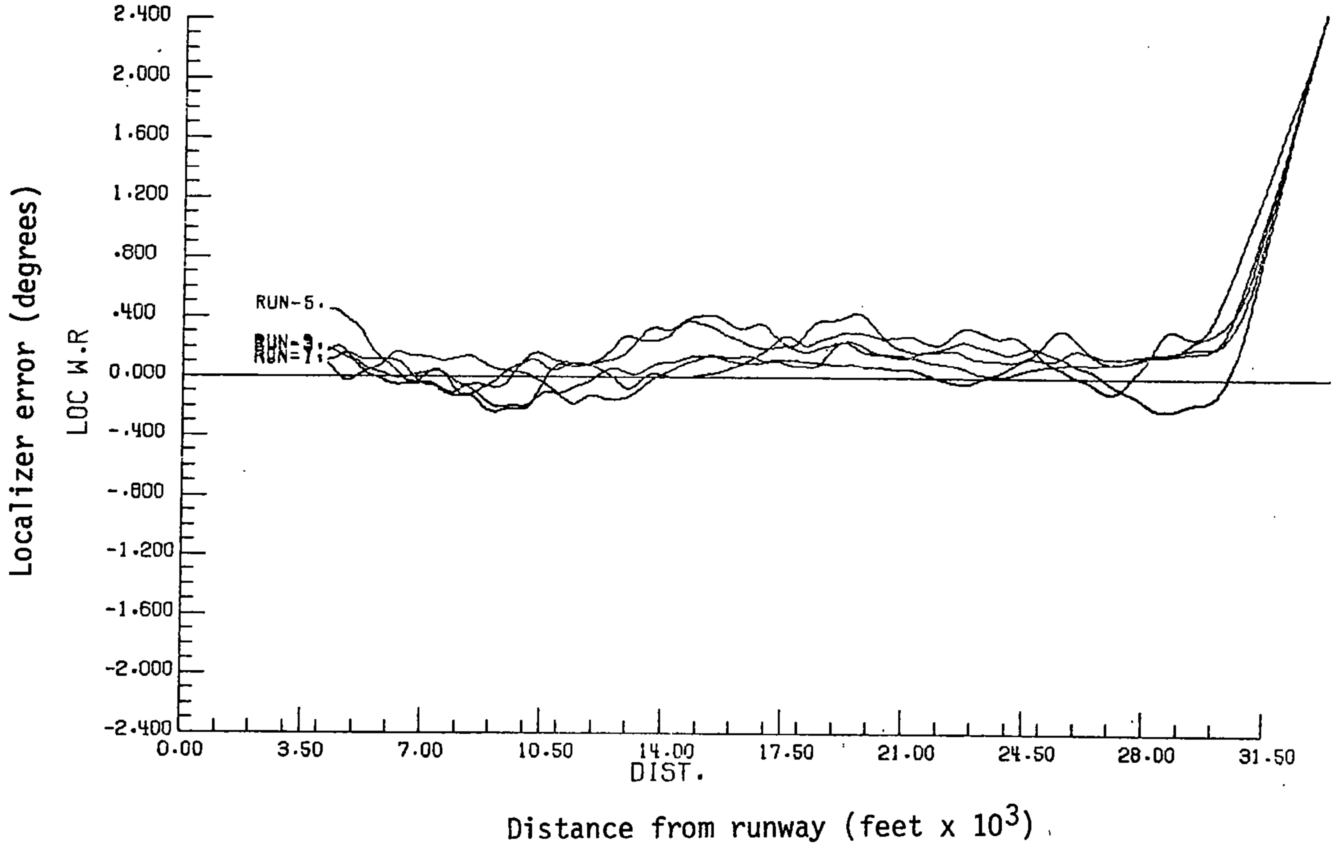
DATA RUN PLOT, CDI

This plot shows angular localizer error versus distance from the runway for all five CDI runs for one of the subject pilots. Localizer error in degrees is presented on the ordinate and distance from runway in thousands of feet is on the abscissa. Each run began with the airplane to the left of the localizer about 5.3 nautical miles from the runway (top right of plot). The airplane then intercepts the localizer about 5 miles from the runway and tracks inbound until an automatic reset occurs at a range of about 4000 feet. This plot is typical of each subject pilot.



DATA RUN PLOT, PCTI

This plot shows the five PCTI runs for the same pilot that flew the CDI runs in the previous plot. Higher system frequencies and smaller localizer errors are observed with the PCTI.



PILOT COMMENTS

Pilot comments indicate that the PCTI was easy to interpret and provided more useful information than the conventional CDI. In particular, the PCTI provided lead information on the localizer and solved the problem of finding the correct heading to compensate for wind. The pilots were less concerned with localizer error using the PCTI since keeping the rate needle centered automatically kept the localizer error near zero. When errors did develop, the pilots would bank the airplane into a turn until the localizer rate indicated a return to centerline. When the localizer error zeroed, the pilots would turn the airplane to zero the localizer error rate. Very little use of the directional gyro was reported by the pilots. The reduced scanning tended to lower reported pilot workload while the higher system frequencies tended to increase workload. The result was that reported workloads with the PCTI and the CDI were about the same.

- ABOUT THE SAME WORKLOAD, PCTI MEANS LESS SCANNING BUT TIGHTER CONTROL
- LESS LATERAL WORKLOAD AND MORE TIME FOR GLIDESLOPE
- PCTI EASY TO INTERPRET
- USED BANK ANGLE TO SET RATE NEEDLE IN GOOD POSITION THEN ROLL LEVEL AND WAIT FOR LOCALIZER TO CENTER, VERY LITTLE D.G. USE
- LESS CONCERNED WITH LOCALIZER, JUST KEEP RATE NEEDLE CENTERED
- IGNORE RATE DURING LARGE CORRECTIONS AND USE IT TO STAY ON LOCALIZER ONCE THERE
- SOLVED PROBLEM OF FINDING THE CORRECT HEADING
- PROVIDES LEAD INFORMATION ON LOCALIZER

CONCLUSIONS

The pseudo command tracking indicator (PCTI) was designed to aid pilots during ILS approaches. The PCTI display was evaluated in the General Aviation Simulator using eight instrument-rated pilots. The results showed a 42 percent reduction in localizer mean RMS error with the PCTI when compared with a conventional CDI display. The PCTI display aided the pilot in compensating for wind drift and in correcting for wind- and turbulence-induced deviations from centerline. No significant changes in pilot workload or glideslope RMS errors were noted.

- PCTI DISPLAY DESIGNED TO AID PILOT DURING ILS APPROACH
- DISPLAY EVALUATED IN GA SIMULATOR WITH EIGHT SUBJECT PILOTS
- FORTY-TWO PERCENT REDUCTION IN LOCALIZER MEAN RMS ERROR
- NONSIGNIFICANT CHANGES IN GLIDESLOPE TRACKING OR PILOT WORKLOAD
- KEEPING THE RATE NEEDLE CENTERED WILL AUTOMATICALLY KEEP THE LOCALIZER NEEDLE CENTERED
- SOLVES PROBLEM OF FINDING THE CORRECT HEADING IN WINDS