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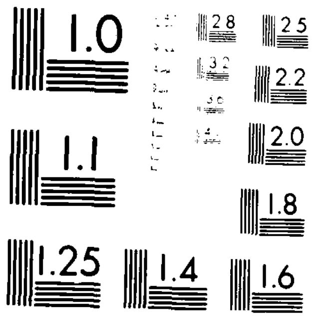

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Systems Technical Memorandum 65

AN INTERIM REPORT OF AN ANALYTICAL EVALUATION OF THREE VISUAL APPROACH SLOPE INDICATORS

Jane Millar

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AN INTERIM REPORT OF AN ANALYTICAL EVALUATION OF THREE VISUAL APPROACH SLOPE INDICATORS

by

Jane MILLAR

SUMMARY

This memorandum is intended as a concise summary of the major findings of an analytical review of published literature about three Visual Approach Slope Indicators; T-VASIS, Red-White VASIS and PAPI. Performance data, ergonomics of the designs and operational requirements of the landing aids are considered. This memorandum and the fuller report, currently in the process of publication, are part of an ARL series on related topics.

POSTAL ADDRESS: Director, Aeronautical Research Laboratories, P.O. Box 4331, Melbourne, Victoria, 3001, Australia.

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1. INTRODUCTION

Cybernetics Group at ARL are undertaking an evaluation of Visual Approach Slope Indicators (VASIs) in conjunction with the Australian representatives from the Department of Aviation to the International Civil Aviation Organisation (ICAO). VASIs are systems of lights which are installed near runways to signal information to pilots approaching to land. The first step in this evaluation was to undertake a theoretical analysis of the previously published information about three VASIs. Two of them, T-VASIS and [Red-White] VASIS, are approved by ICAO for use by turbojet aeroplanes. The other, PAPI, is under consideration by ICAO as a third alternative and perhaps as a replacement for Red-White VASIS.

The major findings of one study (Ref. 1) are presented here as an interim report in a concise form to enable quick reference to the salient points. A previous draft of this paper was presented to the ICAO AGA/81 meeting in Montreal (April 1981) by Mr J. Arnold as a contribution to the debate about VASI standardisation. The issues are elaborated in the complete version where a fuller explanation is given.

2. RESULTS

2.1 Performance Data

Comparative evaluations between, or individual assessments of, Red-White VASIS and T-VASIS have been undertaken in three countries (Australia, UK and USA) during the last twenty-five years (Refs 2, 3, 4, 5, 6, 7, 8). Objective measures of performance recorded during experimental tests have consistently shown that T-VASIS is the more precise and sensitive aid (Refs 2, 3, 4, 5).

Subjective opinions of pilots concur with the objective performance differences (Refs 2, 4, 7, 8). In one operational evaluation Red-White VASIS was shown to have no effect on the probability of an undershoot accident occurring; T-VASIS substantially reduced this probability (Ref. 3).

Although assertions about the performance of PAPI are common (Refs 9, 10, 11, 12), the few objective measures that have been reported are difficult to evaluate, principally because the experimental designs are not adequately reported and statistical comparisons have not been made. The data from the two evaluations describing flightpaths seem to conflict. In Reference 13 (which analysed 72 trajectories) a symmetrical distribution of deviations around the nominal glideslope was reported while the graphs in Reference 14 showed a displaced distribution where approaches were more likely to be low. The results from Reference 13 cannot be further evaluated because no baseline (such as a control 'no aid' or another VASI condition) was provided. The most useful results appear in Reference 14 but only eight trajectories from medium-sized aircraft were presented; the sample size is too small and the results cannot be extrapolated to large international-class aircraft. The results apparently refer to a PAPI configuration using 10' intervals (Refs 14, 15) and if this is true then the data cannot be used to support the case for PAPI set at 20' intervals because the sensitivity of each system is different.

Pilot opinion about PAPI has been sampled in at least four independent evaluations (Refs 9, 10, 11, 16). Only Reference 16 provides reliable information; References 9 and 10 were not reported in a form amenable to comment and Reference 11 (this survey was repeated at two airports) was undoubtedly biased by the form of the questions, the self-selection of subjects and the publication of laudatory comments in general aviation magazines before and during the time that the surveys were conducted (eg Refs 17, 18, 19, 20). Reference 16 was intended as a 'quick' survey and the questions were not very detailed. The pilots did favour PAPI over Red-White VASIS, but the proportions were not as large as predicted by References 9, 10 and 11, and about half the pilots expressed no preference for either system.

In general, the PAPI evaluations have concentrated on operational situations rather than experimental trials, pilot opinion has been used as the main indicator of performance and poor experimental design of several evaluations has negated their intended purpose. Operational tests are premature since PAPI specifications are still being altered (see Refs 11, 14, 21) and adequate statistical data describing either subjective or objective measures have not been published.

2.2 Ergonomics and Operational Considerations

2.2.1 Siting problems

(i) Threshold clearance and ILS compatibility for long-bodied aircraft

Aircraft with large aircraft-wheel to pilot-eye height (eg B747) can be accommodated by T-VASIS without modification because adequate wheel clearance can be achieved by selecting a different approach corridor. T-VASIS provides four extra approach corridors which delineate approach paths very close to 3° and which have different aiming points spread longitudinally down the runway. The ILS signal is constant for each glidepath (Ref. 12).

Both Red-White VASIS and PAPI require modification. The 3-bar solution for Red-White VASIS is unsatisfactory because large aircraft must approach at a steeper angle (3.5°) and the ILS signals are incompatible with the VASI signal (Ref. 12). The most recent solution for PAPI is to widen the 'on course' sector and to move the bar further upwind from the threshold on runways used by larger aircraft (Ref. 21). No test results have been reported so far about the success of this newest solution. (Other solutions, including a 2-BAR PAPI, have not proved successful.)

On runways where PAPI is installed upwind of the ILS origin, all aircraft will be required to touch down further from the threshold. It is thought that pilots may be tempted to land short of the PAPI bar on runways where they are familiar with the airport topography if taxiways have been positioned to assist a quick exit for landings aimed at the ILS origin. Consequently, the risk of an undershoot may increase.

Moreover, it seems that at least two PAPI configurations will be required; this is not a good idea as a pilot of a smaller aircraft (say a B727) may be required to land on successive occasions at airports where each has a

PAPI with different sensitivities installed. Transfer of training between the two may cause interference so that tracking performance is degraded on each system.

(ii) Compatibility with subsidiary ground traffic systems

T-VASIS has been criticised by Reference 12 because it is reputed to be difficult to site between runways and taxiways. The citicism ignores the adaptability of T-VASIS specifications outlined by the designers of the system (Refs 2, 3) and which have been endorsed by ICAO in Annex 14.

The spacing between the bars in Red-White VASIS, and hence the minimum size of the approach channel, is constrained by the ability of pilots to discriminate between the bars at range. Similar trouble has been encountered in siting 2-BAR PAPI, which is a more attractive solution to the ILS/threshold clearance problems than the 1-BAR PAPI alternative chosen in Reference 22 and under consideration for endorsement by ICAO.

2.2.2 Atmospheric effects

Adverse metereological conditions (such as mist, fog, rain, dust and/or industrial pollution) have a much larger effect on the discrimination of hue than on the perception of the presence or absence of light. PAPI and Red-White VASIS coding are particularly susceptible to alteration or interference from atmospheric conditions because the pilot is required to differentiate between coloured light signals.

The interpretation of T-VASIS signals does not require discrimination of hue. T-VASIS, as with most VASIs, is susceptible to light scattering effects that may slightly alter the angle of emitted light under some conditions (e.g. light ground fog).

2.2.3 Slots versus lenses

Objective lenses are not recommended to be used in VASI boxes because dirt or moisture can collect on the lens surfaces and scatter light thereby degrading or destroying the integrity of the signal. Red-White VASIS and T-VASIS have slot-type box options which avoid this problem. The only commercial PAPI boxes that have been used were constructed using objective lenses. A solution to keep the lenses free of moisture has been suggested in Reference 10 but the problem of dirty lenses may be exacerbated (Ref. 23). Slot-type boxes are incompatible with PAPI specifications (Ref. 14).

2.2.4 Installation and maintenance

A considerable amount of emphasis has been placed on easy installation and maintenance of VASIs (Refs 11, 24). All VASIs require solid foundations and until the soil has settled checking of the emitted light directions will be required. Flight testing of systems probably would not be necessary if suitable checking equipment were developed. Installation costs should be considered as being of secondary importance at major airports.

Red-White VASIS is difficult to align because the transition zone interferes with the perception of the edge of the coloured sectors under some conditions such as when the sun is low in the sky or in bright sunlight (Refs 12, 24). Consequently, the system requires a good deal of checking.

2.2.5 Tracking guidance

(i) Categories of information

There are insufficient categories of information provided by Red-White VASIS to allow accurate tracking (Ref. 2). PAPI and T-VASIS provide five and seven categories respectively; in general larger numbers of categories are considered to be better for accurate tracking.

(ii) Interpretation of the signals

Easy interpretation of the signals is hampered in Red-White VASIS and PAPI because director-type codes are absent, augmented cues are used in the 'on glideslope' signal, the gross undershoot signal is part of the normal set of signals and red light is used to indicate a safe condition. Additionally, the information provided by PAPI is displayed horizontally, orthogonal to the plane through which the pilot must control his aircraft, and some pilots have commented adversely (Ref. 9). T-VASIS has none of these deficiencies.

(iii) Frequency of viewing the signals

A simulator experiment (Ref. 5) has shown that pilots may be prone to miss signal changes in Red-White VASIS because the changes are too infrequent. On the other hand, pilots may observe VASI signals too frequently and become distracted or fascinated until too late to accomplish a transition to the flare and landing stage of the approach. (Target fixation is an analogous phenomenon in fighter pilots.) PAPI design has been optimised to provide information until very late during the approach (at about 50 ft AGL, which is equivalent to a short range from the threshold).

The fact that pilots can see the signals changing at a late stage on finals may lull them into the false security that they will be able to alter their flight path late on approach when in fact aircraft inertia and the pilot's own time to decide and to react may exceed the available time.

T-VASIS signals 'break-up' earlier than PAPI (at about 100 ft AGL at night) but most pilots do not comment adversely about this aspect (Refs 2, 3, 4, 7, 8). According to References 12 and 24, Red-White VASIS signals seem to 'break-up' too early (at about 200 to 300 ft AGL) resulting in a large scatter of touchdown points.

(iv) Sectors versus corridors: angle versus height

The error feedback in PAPI is displayed by changes in coloured light sectors and expresses angular deviation from the nominal glideslope. In T-VASIS the feedback displays height deviation directly because the corridors are parallel or almost parallel-sided with only a small contribution from angle. Red-White VASIS provides qualitative information only.

Past experience with another VASI developed for transport aircraft, the Precision Visual Glidepath (PVG), has highlighted two main concerns about error which is expressed in angular terms. In angular systems information about height deviation is range dependent. It was claimed by Sparke (Ref. 25) that a pilot requires height information on an absolute scale rather than a scale which changes depending upon range.

It is thought by the current writer that the flight path of an aircraft approaching to PAPI may be too oscillatory (certainly at long range) because angular deviations are provided as in Red-White VASIS (see Ref. 24). The sensitivity of an angular system cannot be optimised for both ends of the approach simultaneously; only one or the other end can be properly adjusted. If the system is too narrow, late in the approach the signals will almost certainly change, even on a relatively good stabilised approach.

Similarly, if the system has been optimised for close range it should be carefully tested for sensitivity with a number of different pilot-aircraft combinations, especially heavy aircraft, because of their slow machine response times.

T-VASIS avoids these problems because the boxes are spaced longitudinally down the runway and the sensitivity of the system can be adjusted for the whole range of the approach. Red-White VASIS has a limited ability to be adjusted for range and flight paths may be oscillatory (Ref. 24).

2.2.6 Redundancy of information

If one box fails or it is occluded from the pilot's view, T-VASIS provides enough redundant information for the pilot to determine where he is on glidepath. A failure of a PAPI box will result in only three signals being seen instead of four. This is not safe especially if the last 'too low' box fails as no ancillary information is provided. A failure of a Red-White VASIS box will result in reduced visual range of one of the bars.

2.2.7 Detection of wind shear

It would be expected that any VASI which provides quantitative information about elevation would facilitate warning about the presence of wind shear. T-VASIS has not been specifically tested. Reference 26 tested pilots' ability to detect wind shear from avionics, PAPI and external visual cues and found that pilots could distinguish the presence of vertical wind shear. However about one-third of the responses citing PAPI as a cue were incorrect and pilots thought wind shear was present when it was not. In another simulator experiment (Ref. 27) pilots did not find Red-White VASIS a useful cue.

3. CONCLUSIONS

It is concluded that T-VASIS is a precise and sensitive aid which substantially fulfils ergonomic requirements and satisfies most operational constraints. It is concluded that Red-White VASIS contains a number of deficiencies including colour coding, inadequate feedback about deviations, difficulties with aligning the boxes and incompatibility with instrument (ILS) information. The signals are also particularly susceptible to interference from metereological conditions. Red-White VASIS should not be used in Australia.

It is predicted that PAPI may also be inadequate because it contains many of the design faults of Red-White VASIS. Objective lenses have been used in the boxes and colour coding is incorporated. (Even though the transition sector has been minimised the major objections to colour coding have not been overcome.) No satisfactory solution to siting PAPI has been tested to date.

This prediction is based mainly on ergonomic principles because performance data about PAPI is limited and of poor quality. The system has not been objectively tested with aircraft of the intended user-population and most of the claims for PAPI superiority have been bland assertions without supporting data.

It is recommended that PAPI should not be considered for routine operational use until it has been properly evaluated in a controlled experimental environment. Further, because of the ergonomic deficiencies, PAPI should not be installed in Australia for operational use by turbojet aeroplanes because it appears at this stage that T-VASIS is substantially superior.

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17. Imprint Aeronautical Research Laboratories, Melbourne.		
18. Document Series and Number Systems Technical Memorandum 65	19. Cost Code 73 2265	20. Type of Report and Period Covered Interim
21. Computer Programs Used –		
22. Establishment File Ref(s) M2/793		