T-Visual Approach Slope Indicator System (T-VASIS) versus Precision Approach Path Indicator (PAPI) – the debate revisited.

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Abstract *Two visual approach slope indicator lighting systems are in use in Australasia. These systems are designed to ameliorate and overcome the visual illusions associated with the approach and landing manoeuvre of aircraft. Using a flight simulator, 14 student pilot candidates, with little actual flying experience, 'flew' 10 approaches using PAPI and 10 approaches using T-VASIS. The approaches were 'flown' in various flight conditions including low visibility. The visual approach slope indicator lighting system was randomly assigned to each experimental condition. Results indicated that overall, there was less deviation from a correct glidepath when the approaches were 'flown' using T-VASIS. A post-flight survey indicated that participants found T-VASIS to be more intuitive. The results are discussed with reference to the prevailing preference of PAPI over T-VASIS by aviation authorities.*

Introduction

Statistically, the approach and landing phases of flight are considered to be the most dangerous with a high percentage of aircraft accidents occurring during these phases (Clark and Antonenko, 1993, p.49). Visually maintaining the correct approach path just prior to landing can be a demanding exercise in conditions of poor visibility, in rain and at night. Such demands on the pilot can be compounded by making the approach to land onto a runway with an up-slope or down-slope or by flying into an approach area with little foreground lighting or no ambient light – the black-hole approach, (Hawkins, 1993).

Visual approach slope indicator lighting systems can help the pilot overcome the visual illusions that might otherwise result in an undershoot or overshoot situation in the final stages of the approach to land. In Australasia, there are two approach slope lighting guidance systems: the T-Visual Approach Slope Indicator System (T-VASIS) and the Precision Approach Path Indicator (PAPI), (Nolan, 2005). While both systems are approved for use by the International Civil Aviation Organisation (ICAO), according to Clark (1999) the T-VASIS system is under a threat of obsolescence because the colour-coded United Kingdom PAPI system is cheaper to install and maintain. However, Clark (1999) also reports that pilots familiar with the Australian-developed T-VASIS system generally praise it.

T-Visual Approach Slope Indicator System (T-VASIS)

The T-VASIS consists of 20 lights with 10 placed either side of the runway centre line in the form of two wing bars of four lights each with bisecting longitudinal lines of six lights. The pilot on glideslope will see a horizontal line of four white lights. When above the slope the pilot will see an inverted white 'T' with one, two or three white 'fly

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down' lights visible. The higher the aircraft is above the correct slope the more 'fly down' lights are visible.

The correct 'standard' slope is three degrees [2.97°] with an eye height of 15 metres over the runway threshold. When installed at a runway with an Instrument Landing System (ILS), the approach slope indicator is compatible with that of the ILS, (Nolan, 2005, p.32).

When below the correct approach slope the pilot will see a white 'T' and the lower the aircraft is below the correct slope the more 'fly up' lights will be visible. When well below the approach slope the pilot will see the three longitudinal lights in the 'T' as red. (See figure 1.)

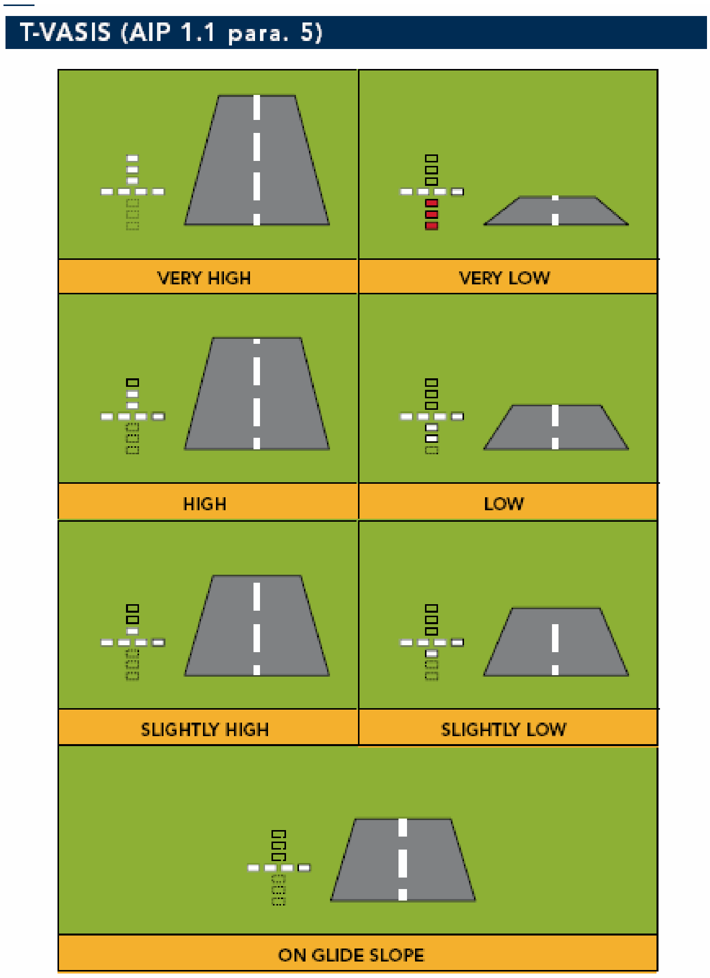


Figure 1. T-VASIS displayed indicators. (Civil Aviation Safety Authority, 2010 p. 228)

Precision Approach Path Indicator (PAPI)

PAPI is made up of four equally spaced sharp transition multi-lamp lights, mounted horizontally as a 'wing bar' on the left-hand side of the runway as viewed on approach. On the correct approach slope the pilot will see the two lights closest to the runway as red and the two lights farthest from the runway as white. If above the correct approach slope the pilot will see the light closest to the runway as red and the other three lights as white. If further above the correct slope the pilot will see all lights as white.

If below the correct approach slope the pilot will see the three lights closest to the runway as red and the farthest as white. If well below the correct approach slope the pilot will see four red lights. As with the T-VASIS system, when the runway has an ILS, the PAPI must have the same approach angle as the ILS and be located to achieve the same threshold wheel crossing height, (Nolan, 2005, p.33). (See figure 2.)

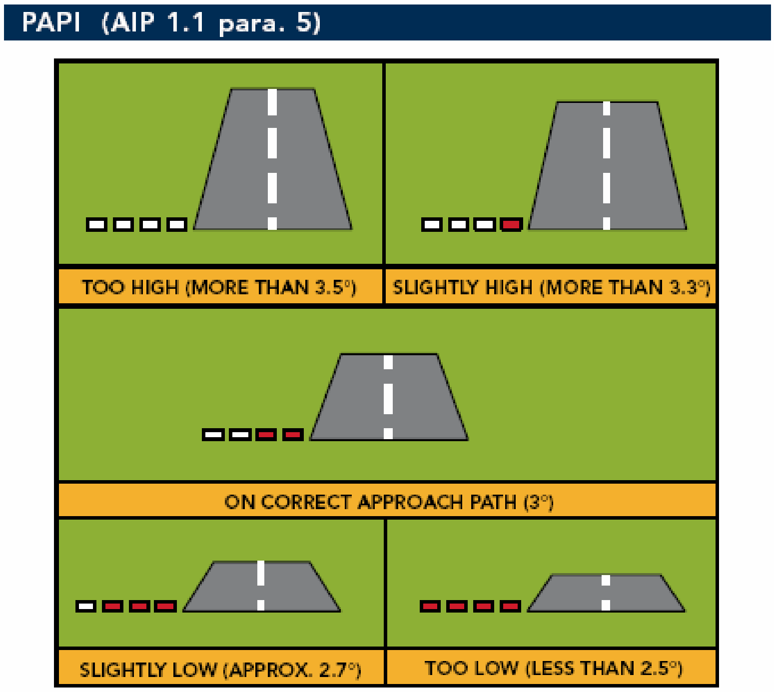


Figure 2. PAPI displayed indicators. (Civil Aviation Safety Authority, 2010 p. 229)

In the 1950's much work was carried out at the Aeronautical Research Laboratories in Melbourne to compare the relative efficacy of the Farnborough-developed Angle-of-Approach Indicator; the Red-White system; the Precision Visual Glidepath system and the Tee Visual Glidepath (TVG) system. The last evolved into the T-Visual Approach Slope Indicator System (T-VASIS), (Day, 1999). According to Day (1999) some 50 pilots and non-pilot observers were bussed to the top of a small mountain range adjacent to Avalon airport (not far from Melbourne) where they were asked to respond to misalignments in the visual indicator systems on the Avalon runway.

Testing of the various approach indicator lighting systems was also carried out by ground observers. These ground observers used theodolites to track and record aeroplanes on approach. This work also involved the subjective assessments of the Lockheed Electra flight crews as they performed the many approaches to land, (Day,1999).

Day (1999) reported that the Tee Visual Glidepath (the precursor of T-VASIS) performed better than the two other systems in terms of both objective theodolite measurements and subjective assessments by the pilots.

Millar (1984) carried out an analytical comparison of the three Visual Approach Slope Indicators (VASIs) approved by the International Civil Aviation Organisation (ICAO) for use by turbojet aeroplanes: VASIS, T-VASIS and PAPI. Millar (1984) used published performance data including approach path measurements and pilot opinion and found that the T-VASIS is a more precise and sensitive aid than the red-white VASIS system. Millar (1984) postulated that, based on the relative performance of the VASIS and T-VASIS and the problems associated with the red-white VASIS system, PAPI would perform less satisfactorily than T-VASIS. Millar (1984) suggested that

PAPI be evaluated using objective measures in a controlled experiment with transport aircraft.

The present study was carried out using a flight simulator in order to determine if there is a difference in pilot ability to follow a correct glidepath using two different visual approach slope indicator lighting systems. Also, a subjective measurement of pilot preference in the use of T-VASIS and PAPI was obtained in order to determine if pilots of limited flying experience shared the same views regarding the intuitive nature of PAPI versus T-VASIS as reported in the literature by industry pilots.

The hypothesis predicted that, under similar conditions of low visibility, the approaches made using T-VASIS would be more accurately flown than the approaches made using PAPI. It was also hypothesised that pilots of limited flying experience would prefer the T-VASIS system over the PAPI system.

Methods

Subjects: The participants in the present study were 14 third-year aviation students from UNSW (Canberra). The ages of the subjects ranged from 20 to 23 years with a mean of approximately 21 years. The subjects all had a minimum of 21 flying hours. Several had logged some 40 to 50 hours but under the terms of their cadetships, no-one had flown an actual aircraft in the preceding two and a half years. The participants had no experience of visual approach slope indicator lighting systems. This study was conducted in accordance with ethics approval granted by UNSW (Canberra) Human Research Ethics Advisory Panel.

Design: Each subject made 20 approach-to-land manoeuvres in a Beechcraft King Air 350 flight simulator using *Microsoft Flight Sim 2004*. 10 approaches were made using T-VASIS onto runway 19 at Brisbane and 10 approaches were made using PAPI onto runway 05 at Adelaide. These two runways were selected as they are of a similar dimension and also involved approaches over water devoid of visual cues. Visual cues relating to different runway aspect and foreground stimuli were therefore minimised. The order of the visual approach slope indicator lighting system was randomly assigned so that, in each of the flight conditions described below, a T-VASIS approach would be followed by PAPI approach and then vice-versa.

The dependant variable was deviation from the correct approach path. Such deviation was recorded by the flight simulator recorder function every second of each flight sequence.

Apparatus: The study was conducted in the Aviation Studio located at the School of Engineering and Information Technology; University of New South Wales (Canberra). The flight console has interchangeable throttle quadrants such that flight can be simulated in aircraft ranging from single-engine piston aircraft to heavy four-engine transport jets. (See figure 3.) The software used was Microsoft Flight Simulator 2004.

The apparatus for measuring the degree of pilot preference for each visual approach slope indicator lighting system was a post-flight questionnaire. The questionnaire is attached as appendix B.

Figure 3 The Aviation Studio showing the Flight Console and the three-screen projected image

Procedure: Participants 'flew' a practice approach in conditions of unlimited visibility (CAVOK) by day from a position aligned with the centre line of the runway at a distance of three nautical miles from the runway threshold and at an altitude of 1000 feet. This practice approach was followed by a sequence of eight approaches made in various conditions of visibility and starting positions. The starting position of the approach-to-land manoeuvres was manipulated so that some approaches started at 1500 feet (high) and some approaches started at from the low position of 500 feet. The approach flight conditions were: night, CAVOK and on slope at three nautical miles; day, CAVOK and starting low; day, CAVOK and starting high; night CAVOK and starting low; night CAVOK and starting high; day through heavy rain and turbulence; night through heavy rain and turbulence; fog such that visibility was reduced to three nautical miles. The final approach [number 10] was made in day CAVOK flight conditions from an offset position so that at the completion of a turn the aircraft could be ideally positioned on final at three nautical miles. Before each approach each participant was briefed as to what approach they might expect; the flight conditions, the starting point as well as the visual approach slope indicator lighting system in use for the approach.

Results

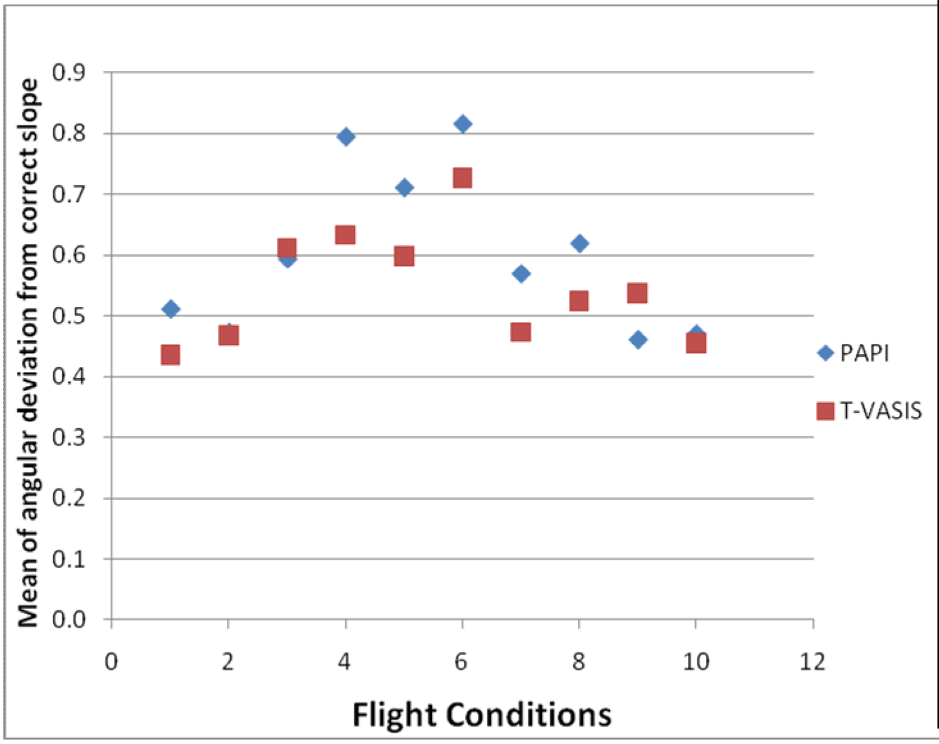
The deviation from the correct approach flight path was recorded by the flight simulator recorder function every second of each flight sequence. An example of an individual participant's flight trajectories for each visual approach lighting system is shown in Appendix A.

The flight simulator deviation measured the parameters of distance to the runway threshold and altitude. A mean angle of error was calculated for each flight condition and the results for all the participants were averaged for each flight condition. The resultant data is shown in table 1.

Table 1. The means of all angular deviations from the correct approach slope for each flight condition and each visual approach lighting system.

	1 Day	2 Night	3 Low	4 High	5 Night Low	6 Night High	7 Rain & Turb	8 Night Rain & Turb	9 Fog	10 Offset	Mean 1-10
PAPI	0.51	0.47	0.59	0.79	0.71	0.82	0.57	0.62	0.46	0.47	0.60
T-VASIS	0.43	0.46	0.61	0.63	0.59	0.72	0.47	0.52	0.53	0.45	0.54

The deviation from the correct approach flight path was less when T-VASIS was the visual approach lighting aid used. The exceptions were for flying condition 3 [day, CAVOK starting low] & 9 [fog, vis. 3NM]. Overall, the mean of the means of the angle of error for each flight condition indicated that T-VASIS produced less deviation from the correct approach flight path. (The results shown in table 1 were graphed and appear as figure 4.)



Flight Conditions

1 = Practice day, CAVOK on slope at 3NM
2 = night, CAVOK on slope at 3NM
3 = day, CAVOK starting low
4 = day, CAVOK starting high
5 = night, CAVOK start low
6 = night CAVOK start high
7 = day heavy rain & turbulence
8 = night heavy rain & turbulence
9 = fog, vis. 3 NM
10 = offset, day CAVOK

Figure 4. Means of angular deviation from the correct slope for the 10 approach flight conditions using PAPI and T- VASIS.

The answers to the questionnaire regarding preferred visual approach lighting system were answered either 'T-VASIS' or 'PAPI'. The responses appear in Appendix C. The total number of responses favouring T-VASIS were summated and calculated as a percentage of all responses. PAPI favourable responses were treated in the same manner. A pie-chart showing the percentage of total responses regarding preferred visual approach lighting system is show in figure 5.

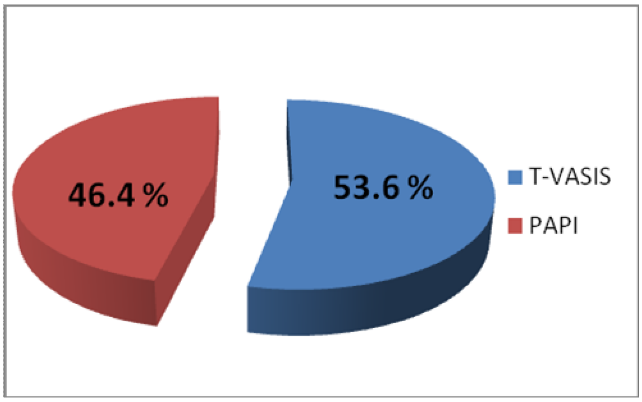


Figure 5. Result of the four-question post-flight survey indicating overall percentage of preference for T-VASIS or PAPI as a visual approach-slope indicator lighting system.

53.6% of all the responses to the questionnaire regarding preferred T-VASIS as a visual approach lighting system. However, in response to the last question: 'Which system did you prefer to use?'; the majority [64%] answered PAPI.

Discussion

The results supported the hypothesis that visual approaches made using T-VASIS would be more accurately flown than the approaches made using PAPI. The results are in accordance with the findings of Day (1999) who used objective theodolite measurements to measure the relative accuracy of three visual glidepath systems.

The results partially supported the hypothesis that pilots of limited flying experience would prefer the T-VASIS over the PAPI system. The results are generally in accordance with Day (1999) who found that pilots' subjective assessments rated T-VASIS more highly than PAPI. The present study deliberately selected participants who had little exposure to flying in order to overcome the bias of experienced pilots that is reported in the literature. It is interesting to note that while a majority of participants in this study found that the T-VASIS as a visual approach system was more intuitive than PAPI however, a majority of participants indicated that they would prefer to use the PAPI system rather than the T-VASIS.

It is of interest to note that despite the objective measurements made by Day (1999) – measurements supported by this study - the use of T-VASIS, as an approach lighting system, is on the decline in Australia. The comments posted by pilots on the social networking website PPRUNE regarding the change from T-VASIS to PAPI on runway 34 at Melbourne International Airport bear testament to the general dislike of PAPI. Aircraft landing on runway 34 in Melbourne are usually held high at 2,500 feet due to the overflying of the adjacent Essendon Airport airspace. The subsequent aircraft descent onto a short final approach, onto a runway with a 2% up-slope is greatly aided by an effective visual approach aid.

This study has not focussed on the effect of each flying condition, [visibility, day/night etc], on the accuracy or otherwise of flying a visual approach using T-VASIS or PAPI. Rather, this study has considered overall results. Further work is indicated where hypotheses regarding the effect of specific flight conditions may elucidate the relative merits of T-VASIS and PAPI as aids to conducting accurate and safe visual approaches under varying levels of visibility.

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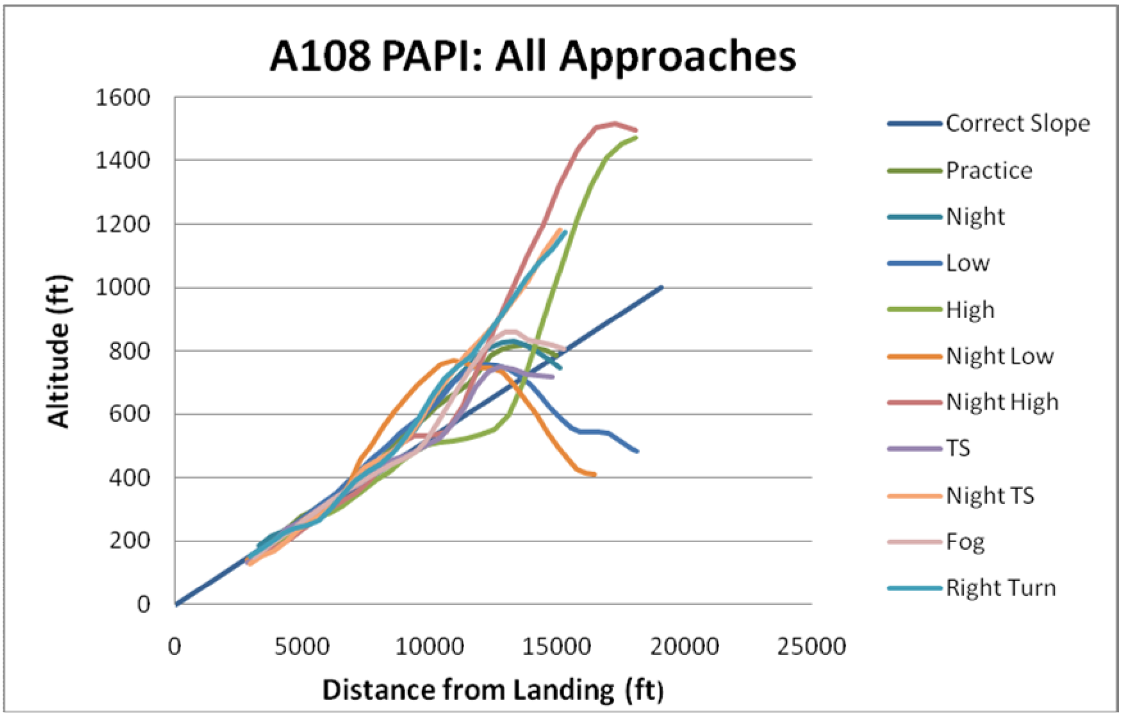
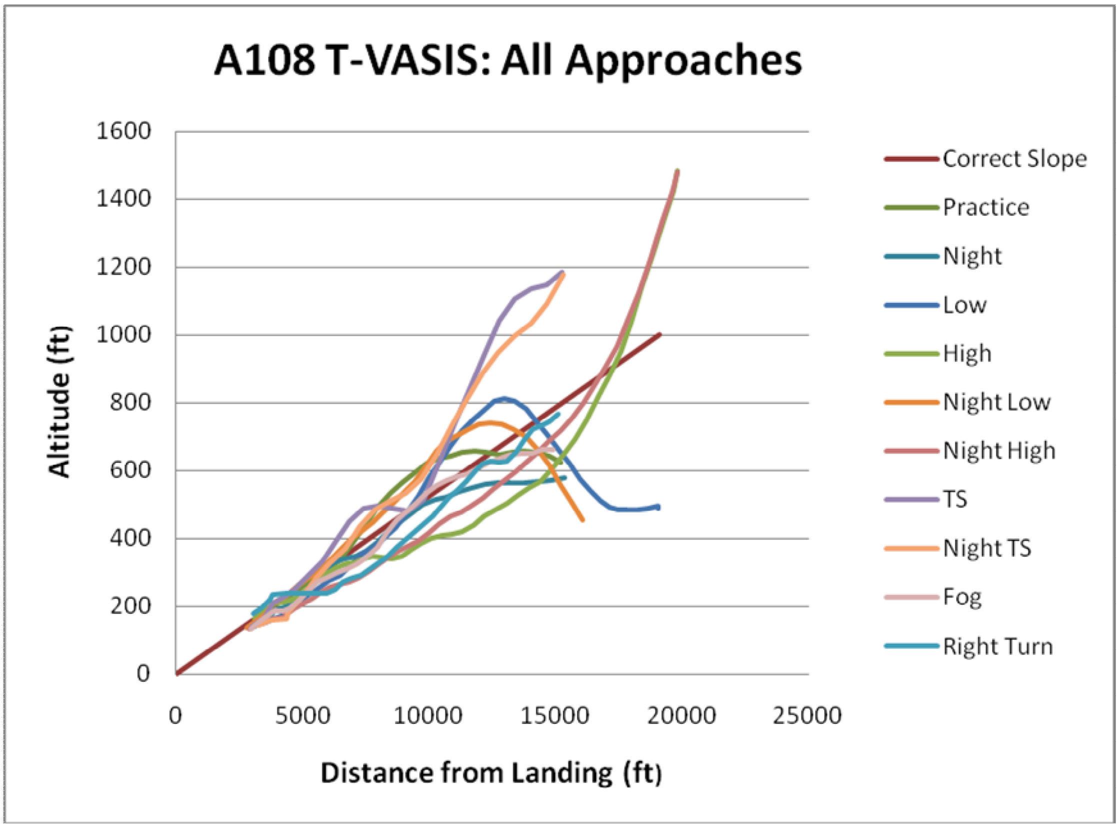
Appendix A

An individual participant's [A108] flight trajectories for each visual approach lighting system as recorded by the flight simulator





Appendix B

Participant Post-Flight Survey

Please circle your answer

Question 1. Which system you think best displays information where you intuitively believe that you are on the correct glide slope?

PAPI	T-VASIS

Question 2. Which system you think best displays information where you intuitively believe that you are above the correct glide slope

T-VASIS	PAPI

Question 3. Which system you think best displays information where you intuitively believe that you are below the correct glide slope (low)?

PAPI	T-VASIS

Question 4. Which system did you prefer to use?

T-VASIS	PAPI

Appendix C

Answers to the four questions on the post-flight survey where P = PAPI and T = T-VASIS

	Survey Questionnaire Question Number				
Subject	1	2	3	4	
A100	T	T	T	T	
A101	T	T	P	T	
A102	T	T	T	T	
A103	P	T	P	P	
A104	T	T	T	P	
A105	P	P	P	P	
A106	P	P	P	P	
A107	T	T	P	P	
A108	P	T	T	P	
A109	T	T	T	P	
A110	T	T	T	T	
A111	T	P	P	P	
A112	P	T	P	T	
A113	P	T	P	P	
Total T	8 T	11 T	6 T	5 T	30 T
Total P	6 P	3 P	8 P	9 P	26 P