competing directly with private enterprise texts on calculator navigation. As it stands, private publishers have nothing to fear and, owing to its brevity and limited scope, this would probably never be a serious objection. Now that GPS has brought the History of Navigation to an end, sextant navigation is becoming irrelevant to yachts and soon there will remain only the hobby (lounge room) market. Perhaps consideration should be given to privatizing the RGO's navigation publishing functions.

Private or public, as long as the *Nautical Almanac* is being printed and being bought, a reference setting out appropriate, practical mathematics could be a convenience and could influence celestial navigation classes (where there is probably an enormous potential readership). Such instructions would take into account how navigation is thought of and how it is performed. Any deviation should be regarded as extraordinary and would need to be explicitly justified. In its present form the *Nautical Almanac*'s calculator segment is unsatisfactory and should either be set to rights or deleted.

KEY WORDS

1. Astro. 2. Computers. 3. Reduction and plotting.

Visual Approach Guidance Indicator Systems

J. R. C. Young

In their paper[1] on 'A history of visual approach guidance indicator systems in Australia', Clark and Antonenko raise a number of points which invite response, although to a certain extent, comment seems to be pre-empted by one of their sentences: 'Haphazard trials of visual approach aids were shown to be readily subject to bias, and were consequently depreciated by Millar',[2] no less.

As one of those deputed to assess them, I should say at once that I hold that the Australian T-VASIS were admirable, despite one major reservation which was subsequently put right and another which I did not fully appreciate at the time.

The paper diverges quite widely from what is purported to be its basic themes: that T-VASIS are better than VASIS or PAPIS because their many gradations allow an assessment of a change in rate of descent; further, that they incorporate a positioning of lights that is ergonomically correct for a descent aid, and that they do not depend upon the colour vision of the pilot using them. It also notes that, like its rivals, it includes supplementary information regarding the horizon line at or near the point of touch-down as an aid to final corrective alignment.

Such are the divergences that my first reaction was to detail my experience with night landing and approach aids dating from those in use in the RAF pre-war, then the old International Lighting System with coloured runway lights, the German system of surface floodlighting, and the completely new system developed as part of the wide-ranging concept of fortress Britain – depending, as the other systems did not, upon the night vision aspects of human capability – the Glim Lamp Flare Path and its developments Drem MkI and MkII. The Glim Lamp Flare Path and Drem systems were abandoned for a variety of reasons, including (*a*) the fact that, in front-line situations, night vision was disabled, and (*b*) the eventual return of peace-time lighting. Other supplementary reasons were the maintenance problem, the amount of real estate involved around so many airports and the very narrow approach path clearly designated.

Another aspect of the paper is its attempt to link the superiority of the T-VASIS to an

Australian Medical Exception to the ICAO/IMO colour vision standards, which is a result of an Industrial Court decision in Australia, giving equal opportunity to pilots who elsewhere are barred from night flight due to incomplete colour vision. It appears that at least the UK contemplates no change. In fact, if one does not meet the colour vision standards, one does not get a licence.

At this point, it is perhaps appropriate to inject an aside: that, when T-VASIS were first displayed for public assessment, the very bright white light used had an excess of ultra-violet emission which meant that 'elderly' pilots found efflorescence of the motes in the aqueous humour of the eye a considerable problem. In Australia, the response to this was not, at first, an abatement of the ultra-violet emission, but vehement statements that the 'elderly' should retire and leave the politics of T-VASIS to younger people, not so affected. It was not a response that won many influential friends at a critical time.

A point raised is that T-VASIS are aimed at minimal disturbance of comprehension as transfer is made from instrument to visual flight – but at what height? Coincident with the full initial installation of VASI-type approach aids, an assessment was made at Farnborough of the view from current aircraft, with the Concorde especially in mind. While it was found that almost all aircraft in use had adequate vision for the manual approach configuration, these investigations revealed that, at the low transition altitudes (200 ft or less) contemplated for automatic approach and subsequent visual landing, VASI approach indicators, with their spread alongside the runway, were difficult if not impossible to see, let alone to integrate into the range of actions required to transfer to visual flight and land, a process which on a 3° glide slope was to be completed in a period of some 23s (excluding the deceleration period) in an aircraft flying between 137 kt and the maximum approach speed of 156 kt; that is, at a rate of descent of some 750 f.p.m., increasing to nearly 1000 f.p.m. at the maximum approach speed at maximum landing weight.

While it was clear that VASIS did not at this late stage in the approach do the job, at least a bar-type aid such as the then-proposed PAPIS gave a simple indication upon which minimal correction action could be initiated if needs be, remembering that no gross error existed, for the aircraft had come successfully down the ILS glide slope.

At that same time, consideration of the three-bar VASIS postulated for use by very large aircraft had made clear an on-going problem. The very large amount of space occupied by a VASI system at a position alongside the runway where existing facilities, of egress and access, were already in place or in some cases urgently required, was a great difficulty, while the proposed PAPIS were simply subject to a 'best possible' decision as to their placing alongside the runway. This combination of disadvantages in VASIS was held to be greater than the problem of the ergonomic unsoundness held to be inherent in PAPIS, and so the decision went against all VASIS.

If a new approach aid proves to be necessary, it can only be as a response to dissatisfaction by present operating pilots, or a clear scientific advantage, or a move into new operational practices. But it will be noted that there has been a succession of night landing systems, including the flarepath system, the surface illumination system, the Glim Lamp systems, and the Calvert International system. Each comprises basic elements: the Money flare indicating airport position was succeeded by the red light on top of the Chance light or the airport beacon, then the radio beacon too, the touch-down system itself with almost invariably some indication of the horizontal such as the T at the end of the flarepath, and an approach aid giving an assessment of the desirable descent path. These elements are always present and each system has within it the seeds of its successor, so the Chance light became the surface illuminations system, now seen as the landing carpet, the descent indicator or angle of approach indicator (ADI) became VASIS then PAPIS, the Drem system's funnels became the undershoot carpet and grid.

Each system has within it also the seeds of its demise. The flare path had to give way to the Glim Lamp system, the beacon at least partially to radio location and approach aids. And, as the speed of approach stabilized and landing sequence was accomplished from a cloud base of 200 ft or less, a simple system giving a wings level check and a last confirmation that the aircraft was not undershooting was all the information that could be assimilated and integrated into the vital 23 seconds at the end of the approach.

T-VASIS, with their indication of rate of descent and rate of change of descent, were in their place to give information on long approaches but they failed, not only to be economical of airport real estate but, as all VASIS did, to give operating pilots usable information in that last vital 23s of transferance to visual flight followed by the process of a successful landing.

It may well be that head-up instruments displays, and the (at least partially) secret methods of vision enhancement that have not yet found their way anywhere into legal non-military night flight, may be catalysts of yet more change. Certainly, it is clear that radio approach guidance, widely used both as a back-up to visual flight and in cloud, has led to automatic approach and landing and even to semi-automatic roll-out and taxiing facilities in which visual aids in all their colourful glory play little part.

Such developments may well give birth to another system that consigns all the foregoing analyses to the limbo of the past and give the opportunity for the development of an aid within a new system that allows for human intervention, should the monitoring process indicate it is essential, at that late moment just before touch-down is initiated. It may well be that colour vision with its known problems will not have a place in this system at any point.

Research upon vision enhancement integrated into the indications on the HUD itself will simplify the interface with the 'pilot's friend' – that integration of flight management system, auto-control and super-human sensors which enhances a pilot's capabilities today and will increasingly do so, and thus in time consign all the earlier analyses into the past. Where GPS will intervene in the approach and landing problem is, as yet, far from clear.

The *Journal* will, no doubt, contain discussion of the issues compelling the birth process of the next system and members worldwide will have their place in its development and fruition. Meanwhile, perhaps it is best to let bygones be bygones.

REFERENCES

[1] Clark, B. A. J. and Antonenko, P. (1993). A history of visual approach guidance indicator systems in Australia. This *Journal*, **46**, 49.

[2] Millar, J. (1984). An analytical comparison of three visual approach slope indicators: VASIS, T-VASIS and PAPI. *Systems Report* 33, Aeronautical Research Laboratories, Melbourne, Australia.

BIBLIOGRAPHY

Calvert, E. S. (1954). Visual judgements in motion. This *Journal*, **7**, 233.

Calvert, E. S. (1948). Visual aids for low visibility conditions. *Journal of the Royal Aeronautical Society*, (July) 439.

Calvert, E. S. (1955). Technical terms in science and technology. *American Journal of Psychology*, **49**, 476.

Calvert, E. S. (1950). Visual aids for landing in bad visibility with particular reference to the transition from instrumental to visual flight. *Trans. Illuminating Eng. Soc.* **15**, 183.

Calvert, E. S. (1957). The theory of visual judgements in motion and its application to the design of landing aids for aircraft. *Trans. Illuminating Eng. Soc.*, **22**, 271.

Wallens, R. M. (1990). *Flying Made My Arms Ache*. Self-Publishing Association, Upton-on-Severn.

KEY WORDS

1. Aircraft lighting. 2. Safety. 3. Approach and landing. 4. Human factors.

Position by Observation of a Single Body

Roy Williams

1. INTRODUCTION. Matti Ranta[1] in his paper published in this *Journal* in May 1990 described a method of computing an observed position from the observation of a single body around the time of culmination. His equations would suggest, however, that the computation is valid at any time that the heavenly body is visible to the observer.

Let us start with Ranta's equation (10) in his paper which we here will label as equation (1).

We will use the symbols:

α to denote altitude
ϕ to denote latitude ($-\frac{1}{2}\pi \leqslant \phi \leqslant \frac{1}{2}\pi$: North positive)
θ to denote longitude ($0 \leqslant \theta < 2\pi$: East positive)
χ to denote declination
λ to denote $2\pi - GHA$
Z to denote the azimuth
V to denote the velocity of the observer
γ to denote the course made good by the observer
Ω to denote $d\lambda/dt$.

In this notation the equation is:

$$\frac{d\alpha}{dt} = \left[V\cos\gamma - \cos(\lambda-\theta)\frac{d\chi}{dt}\right]\cos Z + \left[V\sin\gamma + \sin(\lambda-\theta)\sin\phi\frac{d\chi}{dt} - \Omega\cos\phi\right]\sin Z. \quad (1)$$

2. GENERALIZATION OF THE METHOD OF RANTA[1]. It would seem that at any time other than the time of culmination we can just as well take a series of observations of the altitude, α, of heavenly body and, after fitting a least squares function approximation, $\alpha(t)$, through the data points, we would differentiate to find $\alpha'(t_0)$ at a time, t_0, which we would choose for finding an observed position. Substituting this value of $\alpha'(t_0)$ in equation (1) we could use this equation to find our first and subsequent approximations to Z_n combined then with equations (2) and (3) below to form an iterative scheme for computing $(\lambda-\theta)$ and ϕ at time t_0.

$$\sin(\lambda-\theta)_n = \frac{\sin Z_n \cos\alpha}{\cos\chi} \quad (2)$$

$$\cos\phi_n = \frac{\sin\alpha - \sin\phi_{n-1}\sin\chi}{\cos\chi\cos(\lambda-\theta)_n}. \quad (3)$$