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A Festschrift for Barry Clark

Edited by Philip K. Hughes

DSTO-GD-0211

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Air Operations Division
Aeronautical and Maritime Research Laboratory

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ABSTRACT

This report contains written versions of selected presentations given at a Festschrift for Dr Barry Clark on 7 November 1996. The Festschrift marked the occasion of Barry's retirement and provided a forum to discuss some the work he had conducted during his career and also to discuss ongoing work in Air Operations Division.

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This report contains written versions of presentations given at a Festschrift for Dr Barry Clark on 7 November 1996. The Festschrift marked the occasion of Barry's retirement and provided a forum to discuss some the work he had conducted during his career and also to discuss ongoing work in Air Operations Division. Also included is an article by Barry on his career and a list of his publications.

The theme of the Festschrift was "Applying Vision" and the aim was to recount the various aspects of vision science that Barry engaged in during his time with DSTO. The speakers at the Festschrift described different aspects of Barry's work in vision science and its application to military aviation.

The chair of the Festschrift was Dr Peter Preston and the following presentations were given:

Professor Ross H. Day. School of Psychological Science, La Trobe University

Development and Testing of Three Aircraft Approach Aids at ARL in the 1950s

Professor Tom J. Triggs. Department of Psychology, Monash University

A Consideration of Display Evaluation Methods

Dr Philip K. Hughes. Air Operations Division, AMRL

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Barry Clark and his Rotor Rig in the Vision Laboratory in Building 11.

2. Development and Testing of Three Aircraft Approach Aids at ARL in the 1950s

Ross H. Day, School of Psychological Science, La Trobe University

My involvement with things aeronautical dates back to my PhD days during the 1950s in the University of Bristol when I was appointed to a Research Fellowship by the British Air Ministry to undertake research on perceptual problems in aircraft control. Those were the heady days of the new jet-powered military aircraft with speeds far in excess of those in service earlier with the Royal Air Force. As a result of that research involvement, research of a kind pretty well unheard of in Australia at that time, I was invited by the small research team in the Human Factors Group of the Aeronautical Research Laboratories (ARL) to join the team soon after my return to Australia. Ron Cumming, who headed up the research group, and Russ Baxter, his 2 IC were aware that a good deal of their work fell within the domain of experimental psychology. After consulting with the Head of the Department in the University of Sydney, Professor W.M. O'Neil, they invited me to join the group on a 'consultative' basis and to take part in the program of experiments on the development and testing of visual approach systems. The team consisted of Ron Cumming and Russ Baxter at ARL, John Lane, then Director of Aviation Medicine, and myself. Since I was the only non-Melbourne member of the group I commuted regularly from Sydney, staying for periods of up to a week and taking part in the design, execution and reporting of the experiments which we undertook together.

I remember this halcyon time with enormous pleasure. The task, that of devising a workable, user-friendly final-approach aid, was of real interest and genuine importance, and the team was truly multidisciplinary consisting of two engineers, a medical scientist and an experimental psychologist. Furthermore, the goal was clearly set; to develop a visual final-approach aid functional out to six nautical miles, and, very importantly, acceptable to pilots flying large and small commercial aircraft. What pleased me enormously at the time (and still does) was the spirit of harmonious cooperation that prevailed among this small diverse group of research personnel. We worked closely together in the field and the laboratory with a group of technical staff and the encouragement of the Chief Superintendent, Dr L.P. Coombs, whose enlightened views contributed considerably to the success of the enterprise. In retrospect, the organisation of the group under the inspired leadership of Ron Cumming and the liberal outlook of senior management was a model for applied multidisciplinary research. Fortunately, that awful word was not then in use.

The stage for our research was set in a seminal paper by John Lane and Ron Cumming entitled "The role of visual cues in final approach to landing" published as ARL Human Engineering Note 1 in 1956. This shrewd and insightful commentary both defined the problem for the human operator on final approach and set out ways in which it might be solved. Of course, the ARL group was not the only research team involved in trying to solve the problem. The group led by R.S. Calvert at Farnborough in Britain was engaged in the same mission and had developed the so-called "Red-White" system involving a flight "corridor" signalled by a system of lights.

In the event, the ARL group came up with the Precision Visual Glidepath (P.V.G.) system with lights mounted on frangible poles at one end of the runway and on the ground at the other. When the aircraft was at the required glidepath angle to touch down at the designated point on the runway the pilot saw two outer groups of amber lights and two inner groups of white lights all in alignment, thus precisely defining a glide slope rather than a corridor. When tested in the field and the laboratory (in the latter situation with a miniaturised version) the system clearly worked. However, it was not acceptable on various grounds. One was that authorities did not approve of lights on tall, stayed poles close into the runway even though they were demonstrably frangible.

Another concern was the proliferation of both amber and white lights around busy airports and, therefore, the possibility of perceptual confusion. However, although the P.V.G. system was never adopted it taught us two things: how to work together as a research team and the business of conducting large-scale psychophysical experiments in the field and, literally, in the air as well as in the laboratory with miniaturised versions of the system. With this latter version we simulated landing in heavy rain by spraying water over an aircraft windscreen in front of the observer. It was fun assembling some fifty pilot and non-pilot observers, taking them all by bus at dead of night to the heights of the You Yangs, and have them respond to misalignments of the PVG system set up on the Avalon runway at a distance of 6.8 nautical miles. The Avalon test site gave us the same viewing angle as the glideslope angle on final approach! All of this work was reported in Human Engineering Note 5: "The sensitivity of the precision visual glidepath (P.V.G.) at long range".

Prior to these psychophysical tests of PVG we (Russ Baxter and I) had compared the system with the Farnborough-developed Angle-of-Approach Indicator (A.A.I.) and to the Red-White System by recording the flight profiles on approach with a tracking theodolite and by obtaining pilot comments in carefully structured post-flight interviews. The PVG clearly "won" in this comparison but did not receive approval for the reasons briefly stated above. In due course the engineers in the group came up with another, very clever idea that involved an entirely ground-based system of lights, initially called the Tee Visual Glidepath or T.V.G. The essential feature of the system was a line of three lights on either side of the runway that signalled the correct glideslope for landing. If the aircraft was below the glideslope angle another light forming the leg of a "T" snapped on and if lower than that a second light to increase the length of the leg of the T. Contrariwise, if the approach was above the proper glidepath lights came into view to form an inverted T. Thus the pilot always had a clear signal "on correct flight path: "too low, fly up" or "too high, fly down". The signals were provided by slits at the front of flat box-like structures set at precise positions on the ground at appropriate distances from the runway threshold. They were not hazardous and provided a clear unequivocal signal to the pilot.

In what I now think of nostalgically as our "grand-slam" experiment we compared all three glidepath systems: the A.A.I., the P.V.G. and the newly developed T.V.G. (as it came to be called). Eleven airline captains and four military test pilots served as our observers making three approaches by day and two by night on each system. Flight profiles were again tracked and the subjects were debriefed using a carefully developed questionnaire. We were delighted, even triumphant, to find that TVG performed better than the other two systems in terms of both objective theodolite measurements and subjective assessments by the pilots. These tests were formally reported in our (Baxter, Cumming, Day and Lane) report Human Engineering Note 8: "A comparison of three visual glidepath systems".

I could go on and describe our investigation of duties in the cockpit of the Lockheed Electra making endless in-flight recordings with hand-operated equipment, and endless hours of transcription, and various other issues that we took on at ARL in those early days of human-factors research. However, a good deal of this work has already been set out clearly by Barry Clark whose work this collection of papers is intended to honour (see Aircraft Landing Research at ARL and the Development of the "Tee" Visual Approach Slope Indicator System (T-VASIS), Barry Clark, Aeronautical Research Laboratory 50th Anniversary series, undated).

What seems to me most important to convey in this brief retrospective is that ARL pioneered high-level and effective human-factors research in Australia and, to the credit of all concerned over the last 30 years or so, has continued to do so with distinction as technology and the role of the human operator has changed. Barry Clark became a key contributor in this research in later years.

3. Barry Clark's Scientific Contribution: An Overview

Philip K. Hughes, Air Operations Division, AMRL

3.1 Introduction

Few of us were around 30 years ago and none of us has followed or been aware of all of Barry's scientific exploits since the beginning of his career. Although some of us know isolated parts of his work, none of us knows the complete story. However, if one thing is certain, it is that Barry has left a very clear audit trail of what he has done over the last 30 years. He has left us with an impressive publication record which permits us to see what he has been up to and to assess his contribution.

I know that Barry strongly believes that communication of scientific findings is just as important as doing the work itself. For Barry it is the written record of science in the scientific journals that is paramount, probably because it is permanent, requires some discipline of the author and permits a level of preciseness that I think appeals to Barry.

Barry authored 54 refereed journal papers, about 50 DSTO reports, and about 45 conference papers, and 9 patents. Add to that all the letters, file notes and editorial comments he has written over the papers of others and it is clear that Barry was a productive author.

To keep things manageable, I would like to highlight some of the notable journal papers Barry published in the international scientific literature to indicate the breadth of topics Barry addressed and the lasting importance of the work these papers document.

3.2 Where did it Begin?

Barry entered the publishing stage in 1967 with a plummet. An optical plummet, like a physical bob on a string, indicates the vertical direction but in the optical variety vertical is indicated independently of moderate departures of the plummet from the vertical. This device arose out of a requirement for a helicopter to accurately hover over a fixed reference point on the ground.

There are three themes in this first paper that are worth mentioning because they keep recurring over the next 30 years. First, his interest in optical design. In this paper and many of his subsequent papers there is a figure of some optical design or ray-tracing path. Second, this paper records the beginning of Barry's long interest in aviation. Almost all of his journal papers are relevant to aviation. Third, this paper, and so many of his subsequent papers, describe a device, contraption, or gadget that Barry actually invented or made.

As an aside, I would imagine that almost all of you have had your own papers edited and spelling, punctuation and syntax corrected by Barry. Barry's keen interest in spelling and the use of English began with the publication of his first paper where, in the reference list, his own name was spelt incorrectly. This clear example of scientific fraud was the initial catalyst for his lifelong interest in spelling and punctuation and there began his quest to rid all written material of mistakes and errors.

3.3 Interest in Filters

It is probably true to say that optical filters are as important to Barry as anything else, excluding of course his wife and children. Whether he attempted to use filters to distort the appearance of reality for himself or for others is still an open question. What is true, however, is that Barry published about 25 journal papers concerned in some way or other with optical filters. The filters he was primarily concerned with included welding filters, sunglasses, aircraft windshields, aircrew helmet visors, and motor vehicle windscreens. One important concept that Barry advanced in many of his filter papers was to describe the combined effect of a series of filters rather than the effect of an individual filter. For example, a pilot looking through both his visor and a tinted windshield is potentially more at risk than might be predicted from the individual effects of each filter.

3.4 Welding Filters

The first paper concerned with filters appeared in 1967 in the Australian Journal of Optometry. In this paper Barry derived infra-red transmission limits for welding filters. I think this paper highlights the fourth major theme of his subsequent writings. That is, his concern for the safety of humans in their work environment. The transmission limits were subsequently incorporated in the Australian Standard Specification Z45 "Protective Filters against Optical Radiation".

In 1968 Barry published a paper "Effects of Tinted Ophthalmic Media on the Detection and Recognition of Red Signal Lights" in Aerospace Medicine in which he calculated the luminous transmission function of different optical filters. This function was a normalised ratio of apparent signal to sky luminance that took into account the CIE photopic luminosity function of both normal and colour defective observers. The signal visibility ratio permitted Barry to quantify how a colour defective individual, such as a protanope or protanomal, would see a signal light against the sky through any spectacle or visor filter compared to a colour normal individual viewing the same signal.

By using the visibility ratio and an optimum signal luminance index, Barry made a number of predictions about the visibility of airport and aircraft signal lights against night-time and daytime sky luminances, with and without the effect of tinted spectacles, contact lens, visors and transparencies, and for colour defective individuals.

3.5 Barry's Favourite Colour

It is probably true to say that Barry's favourite colour is red. Although he sees red in many things, it is the detection of red light that has interested him most of all. Red is an important colour for human performance because (1) it usually indicates danger, (2) red signals usually have low intensity and (3) protanopes have reduced sensitivity to red. In the Aerospace Medicine paper, he combined his longstanding interest in filters with the perception of the colour red by protanopes.

3.6 Sunglasses as Filters

Barry has had a keen interest in sunglasses and the effect they have on visual performance. He wrote about 12 papers concerned with sunglasses. The current Australian Standard (AS 1067-1991) specifies optical transmittance and coloration limits and draws heavily on the work reported in these papers.

Barry's interest in sunglasses began with a paper in the Australian Journal of Optometry in 1968. In this paper he surveyed the optical and spectral transmission properties of commercially available sunglasses. The failure of all samples to meet the existing US standards set Barry on a course of contributing to an Australian standard.

3.7 Coloration Limits

In a paper entitled "Coloration Limits for Sunglass Lenses" published in the Australian Journal of Optometry in 1970, Barry described the rationale for limiting the colour of sunglass lenses as described in the new Australian Standard which he helped write. The primary measure was the Red Signal Visibility Factor "R" which described the ratio of transmission of red to white light through a lens. This factor took account of the relative spectral energy distribution of CIE illuminant C, the photopic luminous efficiency curve, and the luminous transmittance of the lens. The practical importance of this index was that it correlated with increases in driver response time to detect red traffic signal lights and vehicle brake lights of different luminances.

Two summaries of his predictions about visibility through sunglasses appeared in the American Journal of Optometry and Archives of the American Academy of Optometry in 1969 as "Colour in Sunglasses" and "The Luminous Transmission Factor of Sunglasses".

Although much of this work originated in the road environment, Barry applied it to aviation and his conclusions and predictions were described in "Consequences of Tinting in Aircraft Windshields" in the Journal of the American Industrial Hygiene Association in 1972. In this paper he described how tinted windscreens could adversely affect visual acuity, brightness discrimination, and the appearance of coloured signal lights.

3.8 Aircraft Transparencies

In 1971 Barry wrote a paper in Clinical Aviation and Aerospace Medicine entitled "Vision Loss from Windshield Tinting in a Night Visual Flying Accident". In this paper Barry described a possible set of circumstances that led to the crash of a light aircraft on a mountain in clear conditions on a moonless night. In the paper Barry described how interior cabin lighting may have reduced the pilot's ability to detect the mountain and how the tinted windscreen may have artificially lengthened the time course of dark adaptation after the pilot switched out the cabin lighting. These factors were proposed as an explanation of why the pilot apparently did not see the mountain.

3.9 The Autocollimating Photokeratoscope

The MSc and PhD years combined two of Barry's most important skills. First, his skill in designing and making optical contraptions, in short the tinkerer that most of us recognise in him. Second, his skill in being able to make precise measurements of physical and biological structures. I think that Barry would forgive me if I said that these two skills characterise him as a scientist concerned with describing the natural world rather than as an empiricist in the strict sense of a scientist concerned with experimental design and the manipulation of independent variables. I think it is true that all of his published work reflects well developed descriptive measurement in contrast to experimentation.

The pinnacle of tinkering and measurement came in the early 1970s with the autocollimating photokeratoscope. His higher degree work was reported in a paper in the prestigious Journal of the Optical Society of America in 1972 describing a new method for measuring corneal topography. It allowed Barry to calculate departures of corneal shape from a reference sphere in terms of asphericity.

Corneal shape, at that time, was difficult to measure in patients who were not anaesthetised because their eyes continually moved. It was also the time at which rigid contact lens were being fitted and it was essential to have an accurate description of the aspheric corneal surface.

3.10 Corneal Topography

What followed was a series of about 15 journal papers in the early 1970s concerned with corneal topography in both normal and diseased eyes. These studies were also in part concerned with the effect of rigid contact lenses on corneal shape and were part of a significant research effort at the University of Melbourne in the early days of contact lens wear. This research was ultimately concerned with accurately fitting rigid contact lenses and determining the dioptric refractive contribution of the cornea to the eye's total refractive power. If rigid contact lenses did not fit properly they had the nasty habit of causing pain or of sticking themselves to the cornea.

Perhaps the most important optical element in the human eye is the anterior corneal surface and it is therefore not surprising that Barry should be interested in its properties. In a 1971 paper in the American Journal of Optometry and Archives of the American Academy of Optometry entitled "Refractive Index and Reflectance of the Anterior Surface of the Cornea", Barry measured the reflectance of the in vivo cornea to be 8%. This was a much higher value than previously thought but was confirmed by optical calculations that assumed the pre-corneal tear film was comprised of 3 different refractive index layers.

In 1972, Barry reported on the mechanical properties of the cornea in a paper entitled "Experimental Deformation of the in vivo Cornea" which was also published in American Journal of Optometry and Archives of the American Academy of Optometry. In this study, an in vivo cornea was applanated and its recovery from deformation monitored after the probe was removed. The poor subject for this study was BAJ Clark himself!

Three review papers concerned with the anterior cornea appeared in the Australian Journal of Optometry in 1973. The first was concerned with different methods for measuring corneal topography, the second with keratometry (measurement of corneal radius of curvature usually taken from two widely separated points on the corneal surface) and keratoscopy (concerned with a complete characterisation of corneal topography).

A series of six papers in the Australian Journal of Optometry appeared during 1973 and 1974. These were concerned with the diurnal time course of corneal topography, variations in corneal topography, and mean topography. In all these papers, the autocollimating photokeratoscope was used and the description of corneal topography was by reference to a diagram showing a 3-D representation of corneal asphericity along several meridians.

Despite Barry's preoccupation with the front-end of the ocular globe, he did manage to move further back in the human eye on three occasions.

First, in a paper published in Ophthalmologica in 1974, Barry reported on a method for modifying a clinical slit-lamp to measure the geometry of the anterior chamber of the eye. An accurate method was required at the time because it was realised there were differences in shape of the anterior chamber between normal eyes and those with angle closure glaucoma.

The second excursion from the anterior cornea was reported in a paper published in the British Journal of Ophthalmology in 1973. At that time the shape of the posterior corneal surface had been measured in only a few eyes because the second Purkinje image is very faint compared to the first Purkinje image. Again, the aim of the paper was to devise an accurate measurement procedure that could monitor the progress of angle closure glaucoma and also to provide information about the refractive contribution of all the optical surfaces in the eye.

The third excursion was all the way back to the anterior lens surface. The shape of the lens surface was reported in a paper in the British Journal of Ophthalmology in 1973.

3.11 Biomicroscopy

The biomicroscope or slit-lamp is an important instrument for viewing the cornea and it is therefore not surprising that Barry should be interested in its optical properties. Barry wrote three papers about the slit-lamp.

In a paper in Ophthalmologica in 1973 he described the importance of aligning the light slit with the eye to the ensure the accuracy of subsequent measures taken from photographs of different ocular structures. The measurements could be in error depending on the degree of misalignment of the light slit and eye. The solution Barry proposed was to centre the reflected beam of light from the cornea on a diffusing screen mounted on the slit-lamp close to the origin of the light beam.

3.12 Barry and Controversy

Some of you may think of Barry as a quiet and peaceable chap not wanting to create problems or a fuss. On the other hand, most of you would agree that Barry is no stranger to controversy and, even at the end of his career, there still remains a degree of controversy. We all know that Barry will put up a good fight, especially when he detects poor or inadequate science or can smell the beginnings of some plot. For Barry, the scientific journals are as good a place to engage in some scholarly discussion and argument as anywhere else. Let me give you four examples.

First, in 1974 Malcolm Townsley took exception to Barry's review paper on keratoscopy and wrote a four page article pointing out that Barry had "mentioned, without analysis, two assumptions which are used to simplify our computation and then makes an incorrect analysis of our integration method". Townsley was apparently a little unhappy about his treatment in Barry's review. Barry then wrote a four page reply opening with "Townsley's re-stated paragraphs do not introduce any need to change the substance of my objections to his method and results". I think this was the end of the matter but I am not sure what was resolved.

Second, in 1973 Barry wrote a scathing letter to the editor of Archives of Ophthalmology demolishing the claims of an author who had foolishly claimed several novel features for his own keratograph invention. Barry bluntly opened with "Donaldsen claimed several new features for his keratograph, but none of these is novel" and "Donaldsen's paper adds little to knowledge in this field" and then set about demolishing the hapless author's paper. The Editor's note "The above letter was submitted to Dr Donaldsen, who conceded the validity of the writer's comments and gave him credit for thorough familiarity with the field" put a quick end to the correspondence.

Third, in Barry's last published paper, entitled "Mismatches Between Driver Visual Capabilities and Road Vehicle Standards" in Road and Transport Research in 1996, he summarised much of his work on filters and visibility to counter the view that vehicle windscreens and sunglasses pose no problem with safety. This paper extended the arguments put forward in 1992 in "Day-time Hazards of Windshield Tinting" which was also published in Road and Transport Research. The motor vehicle lobby had successfully introduced a minimum luminous transmission limit of 75% for vehicle windscreens in the new Australian Design Rule (ADR). This value was lower than the 85% level in Australian Standard 2080-1983. For Barry, this was an unacceptable change. It was against all his work concerning luminous transmission, coloration, the effect of rake angle, the spectrally selective effect of some filters, and the compounding effect of wearing sunglasses in a vehicle with a tinted windscreen. So he took on a US State judge who had let the US vehicle manufactures get away with an even worse relaxation in standards. Barry wrote "These findings directly contradict US State and Federal road safety and law enforcement authorities and contradict scientifically established knowledge" and "The evidence was inappropriately treated". I wonder whether the judge has read Barry's judgement. Although Barry lost the battle, he has not yet given up in this matter.

The 1996 paper was 25 pages in length which is, of course, much too long for any journal. However Barry had a way of influencing the editor so that his paper might be published. How he did it I do not know but at the bottom of the first page is a cryptic message[1] from the editor explaining the intimidation that other authors had suffered.

3.13 Non-journal Papers

So far I have restricted my retrospective to selecting some of the more important contributions that Barry has made through his scientific journal publications. There are, however, amongst the other 120 technical reports, conference papers and other articles, many significant pieces of work. Let me mention just one.

In 1985 Barry wrote a paper entitled "Field Measurement of Visibility" for the Commonwealth Defence Conference on Operational Clothing and Combat Equipment. In this paper he was concerned with measuring the visibility of military objects in complex natural backgrounds. Barry's idea was to use a strip of sand-blasted perspex as a graduated way of increasing optical scattering. The "Scattering Visibility Gauge" was born. It was used to measure the relative contrast of objects by reducing their contrast but maintain an acceptably high luminous transmission so that the visual adaptation of the user was not adversely affected.

No doubt there are many opinions about the visibility gauge and it was a project that never received the support Barry had wanted. It is a pity the detailed calibration of this device was never completed because I think it still has numerous applications in the quantification of visual detection of real military targets through the atmosphere as well as the measurement of visibility of computer displayed sensor imagery.

3.14 Heroes

I hope that through this retrospective I have given some small indication of Barry's contributions. Although all except seven of Barry's journal papers were written as sole author he did have some help along the way. Where did he derive his inspiration from? I think there were three people who are in part also responsible for what Barry has left us with.

I think Barry's principal hero was Richard Blackwell who was the doyen of visibility studies in the 1950s. Blackwell was interested in "making the obvious difficult to see" and I think this concept appealed to Barry. Blackwell wrote a paper in 1954 that essentially shaped Barry's whole career. The title was "Visual Detection at Low Luminance Through Optical Filters (Highway Research Board Bulletin, 1954, 89, 43-61). Barry took all the words in Blackwell's title and made them his life's pursuit.

His second hero was the German Pulfrich who wrote a paper in 1922 that described a spatial illusion of moving objects. No doubt you all have, like many others in the Department of Defence, experienced it. I think Barry delighted in this illusion because it allowed him to engage in a little trickery and to reinforce to management his favourite dictum that "what you get is not always what you pay for".

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[1] "This paper is longer than normally accepted. It has been able to be published in full due to the late withdrawal of other papers."

However, the most influential person on Barry's scientific writings was H. W. Fowler. His book, "Modern English Usage" has been Barry's desk-side companion ever since he bought the 1954 edition. Although Barry might still agree it is modern, I am sure that today there are many of you who are glad to see it packed off in a cardboard box.

3.15 Conclusion

In conclusion, I hope I have presented a fair picture of both the breadth of topics and kind of material that has made up Barry's contribution to the scientific journal literature. I think that Barry's example in this regard is one of the losses that we will experience with his early retirement. There is nobody remaining in this division with the scientific experience that he has and for this reason he will be missed.

4. Some Perceptual Issues in the Aviation Setting

James W. Meehan, Air Operations Division, AMRL

4.1 Introduction

My association with Barry Clark in human factors research spans more than ten years, and the opportunity to describe some highlights of that association today, when we celebrate Barry's scientific contribution, is appreciated. I have selected three pieces of work where Barry and I - and others - have collaborated and which have been both satisfying to do and satisfactory in outcome, and which are antecedents and harbingers of issues that are now attracting our research attention. The first dealt with the phenomenon that has become known as imaging display micropsia, which was the topic of my own postgraduate research. The second was an experimental investigation of the perception of helicopter-rotor sweep that Barry had begun to investigate several years ago. The third is a study, still in progress, of a simulated pursuit flying task with a restricted field-of-view (FOV).

4.2 Imaging Display Micropsia

A paper in the journal Human Factors by Stan Roscoe titled "When day is done and shadows fall, we miss the airport most of all", that Tom Triggs first drew to my attention, raised the issue of imaging display micropsia. This launched me on a course into the very interesting world of human factors in aviation, which still claims most of my attention and working time. In the paper, Roscoe reinterpreted earlier experimental flight performance data that had been collected by him in the late 1940s and early 1950s. Roscoe had fitted a Cessna T50 aircraft with an optical projection periscope in place of the windshield, and had pilots take off, fly and land the aircraft with no other view of the outside world except that afforded by the periscope display. He found that pilots performed most like normal when the display image was magnified about 25%. In the 1979 paper, Roscoe interpreted his earlier findings as a case of accommodation micropsia. This had two immediate outcomes. The first was the controversy that it generated over not only the accommodation micropsia hypothesis, but also over notional remedies for the hypothesised cause. The second was my own immersion in the controversy and the broader theoretical context of it.

In investigating Roscoe's accommodation micropsia hypothesis, the first problem to be faced was how to replicate the imaging display micropsia effect conveniently on the ground, for experimentation in the field and in the laboratory. During a discussion on the problem, Ross Day recounted observations made by Thouless on a sabbatical he had taken at Monash University in the late 1960s. Thouless had observed that objects such as motor vehicles, when viewed through 8-power binoculars, did not appear any larger - they were sometimes reported smaller - but they did appear closer. These observations of Thouless clearly were related to the effect reported by Roscoe, and it was the pondering of this relationship that led to consideration of the potential for replicating Roscoe's effect using the viewfinder optics of a single-lens reflex (SLR) camera fitted with a zoom lens.

There were two practical issues that required resolution. The first concerned the configuration of an SLR viewfinder/zoom-lens optical system for experimental data gathering, and the second was calibration of the optical system for image size, so that measurements of the size of images displayed in relation to their actual angular subtense from the system's eyepoint could be recorded. In solving these problems, discussions with Barry - and also with George Smith - were very valuable, and the successful conduct of numerous experiments with this apparatus is at least partially due their expert advice on the optical arrangement of the apparatus and the likely impact of this on some human ocular functions.

4.3 Helicopter-Rotor Sweep Perception

The second research activity involved a close collaboration between Barry, Philip Hughes, and myself. Not long after I joined DSTO, an experiment being conducted by Barry and Philip, in a building that was due to be refurbished, needed to be completed urgently. The problem being addressed in the experiment was the frequency of helicopter rotors striking objects during manoeuvre in confined areas in close proximity to objects. Rotor-strike literature suggested that there could be a systematic error in estimating the extent of helicopter rotor sweep, and this in turn raised the possibility that underestimation of the rotor's sweep might be a contributing factor.

Barry had constructed a half-scale rotor simulation apparatus, modelled on the dimensions of a UH-1H Iroquois, and a very clever motorised visual-angle invariant pointer for the subject in the experiment to indicate perceived egocentric distance of the rotor tip, whether the rotor was stationary or moving. Preliminary observations had confirmed the hunch that pilots might be underestimating the sweep of a moving rotor, and that this was a contributing factor in rotor-strike accidents. What we did over that summer, before the old vision laboratory was demolished, was to conduct a formal factorial experiment with the apparatus and about a dozen pilots. The variables were rotor direction (clockwise, anti-clockwise) and rotor speed (29, 62, 139 rpm). At the end, estimates were also gathered with the rotor stationary. The mean estimates showed no differences under any combinations of conditions, however, there was a large spread in distance estimations, and analysis of the deviation data showed that errors increased significantly with rotor speed, regardless of direction of motion. In other words, there was no biasing error, merely error, suggesting that rotor sweep was simply more difficult to estimate accurately when it was moving, and it became increasingly difficult as speed of rotation increased. An issue that remains of interest to Barry is the possibility of there being idiosyncratic biases in estimates, analogous to those observed for some oculomotor functions, and this raises the intriguing question as to whether there might be oculomotor factors involved. At present there are no immediate plans - or funds - for follow-on work, but the relevance of this, highlighted recently by the collision of two helicopters involved in operational training, is inescapable.

4.4 Simulated Pursuit-flying Task with Restricted Field-of-View

A third piece of research, still in progress, that brought me into contact with Barry is examining the performance of pilots in a simulated pursuit-flying task, with a restricted and an unrestricted instantaneous FOV. The motivation for this work is the restricted FOV of the helmet mounted displays (HMDs) used in some simulators and also in some of the new cockpit display systems, whose FOV is typically limited to 40 deg (± 20 deg). Although many HMDs project images on a transparent visor so that the outside world may still be viewed directly, so-called "full-immersion" HMDs, such as those that utilise various forms of thermal imaging, obscure the visual field outside the display's FOV.

A restricted FOV affects target detection adversely for two reasons. First, targets outside the FOV simply are not visible. Second, targets near the edge of the field that are visible are less likely to be detected, due possibly to lateral inhibition and related effects from proximity to the edge of the field. The question addressed in the present study was what might be the effect of a restricted FOV on performance in a target tracking task?

The study is being conducted in the research flight simulator at AMRL, Fishermens Bend, using a projected partial-dome display. The task of the subjects is to follow the flight path of another aircraft close behind, similar in some respects to formation flight, under different combinations of conditions. There are two display conditions, an unrestricted instantaneous FOV, and a mask with a 40-deg head-tracked circular FOV that emulates the FOV of a typical HMD. There are two following distances, that is, separation from the lead aircraft, and these are 400 m and 200 m. There are three tasks, all of which require the pilot to keep the target aircraft within a zone designated by a head-up display (HUD) symbol. These are a 10-deg HUD circle, a fixed point, and the flight vector.

Dependent variables will be flying performance measures such as RMS error, and head-movement data will also be gathered. Findings from preliminary experimentation already suggest that the 400 m following distance is too easy, and that the HUD circle and dot produce similar performance, whereas the flight vector produces better performance than the circle and the dot.

These results from the preliminary experiment point to the use of a reduced set of variables for the formal experiment that will follow, and also have provided useful information about head-movement recording. Head movements are an important behaviour to measure, as they have the potential to indicate different demands on the pilot under the various regimes, as well as an indication of where the pilot is likely to be looking. Two important aspects of our attempts to measure head-movement data have emerged. The first is the critical importance of helmet fit for obtaining clean data. Second, there is a need for a good method for analysis of head-movement data to be developed.

4.5 Conclusion

These examples of research work that have brought me in contact with Barry have two aspects that merit remark. The first is that they all have antecedents in areas of human factors research in which Barry has been engaged and in which he has been interested for a very long time. The second is the observation that all three have considerable contemporary importance, and cover topics of interest to defence science in particular, and also topics of general scientific interest. The themes of these particular studies are large in scope, covering human factors, especially human visual performance, and are remarkable in being issues of long standing in defence science, that continue to be of importance, and continue to claim our attention.

5. Some Favourite Visual Optics Topics

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5.1 Summary

The visual environment and achieved visual performance of military aircrew can determine mission success or failure. Applied research into visual displays, optical radiation hazards, visibility, transparency scatter, vision enhancement, helicopter separation judgement and visual landing aids has set challenges in the writer's career. Significant new problems continue to emerge. The complexity of vision research requires a long-term commitment and broad approach. Justification for putting scarce DSTO resources into enhancing aircrew visual performance and reducing visual handicaps and hazards is readily arguable.

5.2 Introduction

This paper follows the verbal presentation of 7 November 1996, but anecdotes have been omitted and explanatory material added.

Optimisation of visual information input, protection and facilitation of perception, and improvement in visual comprehension can all contribute to the success and safety of a military mission, especially in military aviation. Of the many applied research topics in this area with substantial 'smart operator' payoff potential, some of particular interest to the writer include the characteristics of visual displays, eye protection against optical radiation, visibility, transparency scatter, vision enhancement, helicopter separation judgement and visual landing aids. Research on such topics tends to be ongoing because many existing problems are seldom fully resolved, while significant additional problems continue to emerge both as a result of the introduction of new technology and as the human part of manned military systems, rather than the technology, increasingly tends to limit overall mission performance. Unfortunately, a slow but highly economical approach in which maximum benefit is gained by assiduous monitoring and exploitation of the literature does not fit well with a policy favouring '80% results in 50% of the time'. While quick outcomes might be appropriate in some military studies, the prospect of a disastrous '- 80% solution' seems unacceptable in military operator research.

In 1928, Cobb and Moss described four fundamental aspects affecting vision: luminance, size, contrast, and observation time. Of these, contrast was the least understood then and it still is. Much of this paper relates to contrast perception because the potential payoffs are large.

5.3 Visual Displays For Aircrew

5.3.1 Collimated Displays

In the mid-1950s, one of the writer's predecessors at Aeronautical Research Laboratories (ARL, now AMRL), the late Ron Cumming, began Australian research on the optimisation of visual information presentation to aircrew. Such research efforts, world-wide, have led to the best of the present-day aircraft instrument panels being highly effective, but there is still scope for further exploitation of Cumming's boldly innovative approach.[2]

Conventional instrument panels have a limitation in visual flight because of the time lost in the visual transition to and from the panel. Head-up displays (HUDs), in which pilots are presented with information collimated at optical infinity and superimposed on the external view, reduce this loss.

Aircraft-referenced HUDs were in use as fighter gunsights during WWII. Cumming's program included work on *ground-referenced* HUDs (see Clark, 1989). The Sperry Gyroscope Company was working independently on a similar project, but this was not known until some time later when similarity of the ideas was pointed out by the Flight Control Laboratory at Wright-Patterson Air Force Base, Ohio. Only then was it realised that ARL's first publication on the work (Lane and Cumming, 1956) was a month ahead of Sperry's (Coombes, 1963). The ARL overhead mount prototype HUD was first flown in a DC-3 in 1957.[3] Sperry's arrangement was also mounted overhead in a DC-3, but the image stabilisation systems were quite different. The ARL work was funded by the Department of Civil Aviation (DCA)[4] as little military value was foreseen.[5] When the funding ran out after further flight tests[6] at the end of 1960, the Department of Supply tapered the work off. Team member J. R. (Russ) Baxter was seconded to transfer the technology, free, to the USA. The US Federal Aviation Agency provided a technical assistant but was adamant that Baxter be listed as second author of the resulting report (Workman and Baxter, 1962)! Of course, ground referenced HUDs are now standard fitments in all military jet fighters and some other military aircraft. Some commercial aircraft also have them fitted for routine operational use in severe weather.

For pilots, HUDs are a brilliant *human engineering* solution to the problem of seeing important data while looking at the next bit of atmospheric space to be occupied by the aircraft. They are so good at data presentation that the associated loss of external visibility is generally ignored. They are not such a good *human factors* solution. A few years ago, measurements with the Visibility Gauge (see below) indicated that an F/A-18 HUD could reduce threshold visibility distance to an aircraft-like target by at least 30% in bright daylight. The losses in dim light conditions are likely to be greater. HUDs as contributors to incidents and accidents have not been given due quantitative attention by air safety investigators.

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[2] The initial work at ARL ended in the late 1960s when Cumming and all of his research team resigned in protest at management policy.

[3] The valve electronics occupied a box that was about the size of two filing cabinets. The prototype optical head was preserved in the ARL historical collection until most of the collection was mistakenly dumped in the early 1990s.

[4] Dr John Lane was from DCA and later became its Director of Aviation Medicine.

[5] This assessment ranks with the lack of official support for the 'black box' flight data recorder developed at about the same time at ARL by Dr Dave Warren.

[6] The writer, then at Defence Standards Laboratories, Maribyrnong, vacuum coated the beam splitters used in the prototype.

The ANVIS HUD is an-attachment to one side of a pair of night vision goggles (NVGs). It superimposes a collimated data display on the external scene image. This and equivalent devices designed from the outset as head- or helmet-mounted displays (HMDs) combine collimated images with external scenes, as in HUDs, but give a much larger range of viewing directions. Many of the problems of HUDs remain, however, such as suppression of visibility of scene details behind or near the displayed information. In addition, existing HMDs typically appear to have potentially serious faults arising from monocular presentation of the information, leading to retinal rivalry phenomena and conflicts in perceptual cues to localisation. HMDs can certainly extend the circumstances for weapons aiming, but the accident potential introduced has to be understood and contained. This will be a challenge in the current Air Operations Division (AOD) work on HMD standardisation and acquisition.

5.3.2 Stereo Displays in the Cockpit

There are literally thousands of patents for auto-stereoscopic displays in which a stereo pair of optical or electronic images is seen in 3 D (with depth as well as perspective) without the necessity for the viewer to wear special glasses or to look into a device with two eyepieces.

A new form of auto-stereoscopic device was invented at ARL in the late 1980s but demonstration had to wait until 1993 when suitable flat panel displays became available. The allowable range of head movement well exceeds that possible with current HUDs, and the achievable image luminance is so high that readability in full sunlight is assured, as required for the intended use in cockpits. Any tactical advantage of such a device is currently conjectural, but allied countries have identified the requirement for fast jets. Unfortunately, local interest in the military application of this invention has been minimal. An Australian company has done well out of a similar invention intended for domestic use.

5.4 Eye Protection Against Optical Radiation

Electromagnetic radiation in the wavelength range from 380 nm to 780 nm is generally regarded as visible light. The near ultraviolet range, from about 400 nm down to 320 nm, excites fluorescence in the ocular media. Visible fluorescent light illuminates the retina, creating veiling glare that degrades contrast detection. The near ultraviolet has also been implicated as a causal factor in cataract (opacities in the crystalline lens of the eye). Radiation of shorter wavelengths can cause sunburn and cancer, but most of the solar erythemal (reddening) range is normally absorbed in the upper atmosphere by ozone and other atmospheric constituents. Flying can increase erythemal exposure, especially when aircrew visors and aircraft transparencies do not have the level of erythemal uv absorption required.

Erythemal radiation tends to be absorbed in and thereby damage the exposed surface of the eye. Longer wavelength ultraviolet and visible light can reach the retina. Exposure to bright daylight can temporarily reduce sensitivity to dim light (Clark, 1971a). Sunglasses and tinted visors can reduce these effects as well as alleviate discomfort glare (Clark, 1969). Near ultraviolet, violet and blue light has been claimed to cause permanent retinal damage, the so-called 'blue light hazard', but this is controversial. Amber-tinted lenses that absorb blue light subjectively improve vision but objectively degrade it, especially in the 4% of the population with colour vision deficiency.

Visual performance is high in daylight but reduces, gradually at first, as the light levels fall below those of early twilight. Dark filters can cause increases of hundredths of a second in the seeing process and much longer increases in the time required for judgements of distance changes, especially at lower lighting levels (Clark, 1996). Filters can lengthen the time taken by aircrew to detect and react to the sighting of an enemy. New ways of optimising the compromise between visual comfort and response speed appear possible.

The lower limit of near infrared is often considered as 700 nm although visibility extends past 1 µm, with increasing risk to the retina, given sufficiently intense sources. Near infrared generated by ordinary light sources tends to be innocuous to skin or eyes, but many lasers can produce beams intense enough to be hazardous.

Lasers as blinding weapons are subject to international embargo, but history indicates that nations facing military defeat tend to disregard such embargoes. Continuing development of laser systems for other purposes, such as target designation, may also increase their effectiveness as blinders. Present laser protective eyewear generally restricts fields of view, degrades scene contrast and reduces visual acuity. An enemy threat that forces their use has already gained a substantial military advantage. The physics of lasers and the biophysics of laser blinding are much better understood at present than the operational risks and costs of various degrees of aircrew eye protection. All known laser protective eyewear degrades vision.

Simple absorptive filters can reduce the danger of laser blinders, but they only work well in bright daylight when the pupil is small and light loss has a minimal effect on vision. At lesser light levels, the reduction in visual performance becomes appreciable. At night, dilated pupils increase the need for protection, but the required filter density can virtually eliminate external vision. Generally, *less light makes it harder to see* and thereby increases the risk of accidents in driving (Clark, 1996) and flying (Clark, 1971b). The peacetime training use of anti-laser dark filters by aircrew could well cost more in lives and aircraft than enemy use of lasers might ever achieve in wartime.

Present alternatives to dark filters are a patch over one eye (giving just one more chance!), and 24 hour use of NVGs with suitable light attenuators for bright conditions. NVGs are expensive, but far cheaper than aircrew eyes. Developmental versions with false colour images and larger fields of view may have improved daytime acceptability in future.

5.5 The Visibility Gauge

Visibility meters optically reduce the contrast of a viewed scene. Ideally, they should have minimal effect on scene luminance, colour, field of view and resolution, but the Visibility Gauge (Clark, 1985) still appears to be the only kind that complies with these important conditions set by the International Commission on Illumination (CIE). The prototype Gauge is essentially an acrylic strip, grit blasted to near opacity at one end and grading to full clarity at the other. Placed close to an observer's eye, it allows manipulation of the apparent scene contrast. It is less cumbersome than many other methods of evaluating visual performance or tasks. In use, the acrylic strip is moved lengthways until some particular visual test or task is just visible (Figure 1). The contrast transmittance of the strip at that position can be read from a calibration graph,[7] and is a measure of visual performance or task difficulty.

The Gauge was patented in several countries, including the USA. However, Dr J. J. Vos of The Netherlands (known personally through international standardisation activities on sunglasses) subsequently pointed out that an essentially similar device had been described in a German paper in 1921. This paper had been missed by all of the extensive prior art literature searches in the patenting process. The German device was only intended for use in measuring meteorological visibility. Several variants were marketed by Zeiss.

The prototype Gauge was used at ARDU to improve the legibility of the instrument panel labels on the Nomad prototype, and later in an Iroqouis to optimise legibility of the instruments in the first Australian conversion of panel lighting to NVGs compatibility. The procedure was an advance on existing best practice in which instrument luminance is adjusted to perceived or measured equality. Now all critical detail can be maximally legible for any given level of external optical signature.

The panel lighting of all Australian Black Hawks was set up this way at final assembly. Obvious further uses are for optimising camouflage or anticollision schemes, and for determining visibility in accident cases.

5.6 Transparency Scatter

Even when new, vehicle and aircraft transparencies degrade the contrast of viewed objects by light absorption and reflection. Usage inevitably deposits surface dirt that increases light loss by scattering, further reducing contrast. Abrasion from cleaning and from impact with airborne particles also accompanies usage, and increases scatter until replacement is decided subjectively by aircrew or maintainers. Transparency removal before operational tasks and flying safety begin to be affected is wasteful and uneconomic, but delayed replacement carries unnecessary risks. Unfortunately there is no currently satisfactory quantitative method of relating the degree of scattering to the hazards (Clark, 1979).

Many attempts world-wide have been made to devise an instrumental measure of scattering as an objective indicator for serviceability sentencing. These are all unsatisfactory, primarily because scattering characteristics do not have a simple relationship to the degree of degradation of vision. Fine haze on a windshield might scatter as much light as a certain number of raindrops of various sizes, but the visual degradation effects may be quite different. Allen's (1963) photographic study of various types of windshield scattering indicates the complexity of the relationship.

A further problem arises when the transparency is tinted. The transmitted scatter becomes a complicated function of the incident and viewing angles. To cope with this effect, a device was invented in the early 1980s to provide equal light paths for the

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[7] The calibration graph for the prototype is in Clark (1985).

direct and scattered beams.[8] The prototype worked nicely, with direct and scattered light displayed side by side for accurate visual matching while a calibrated attenuator was adjusted. But when it was tried on F-111Cs at RAAF Amberley it failed in several cases to indicate transparency surface crazing. The individual cracks were aligned in an approximately parallel array. In flight, the crazing usually had no visible effect on the external view, but occasionally the sun-transparency-heading geometry would allow total internal reflection at the crack surfaces to produce an extensive blinding image of the sun that completely obscured the external view over a hundred square degrees or more. Crazed transparencies were thus considered to be a flight safety hazard regardless of acceptability according to the prototype scattering indicator or any other existing test method.

Changes in style and materials have made crazing now unusual in motor vehicle transparencies, but another source of anisotropic scattering is universal in windshields of all road vehicles and some ships and aircraft, viz abrasion from windshield wipers. Apparently nobody has yet qualitatively studied how the diffracted line highlight from bright lights illuminating the concentric scratches interferes with operator vision. The sentencing problem remains unsolved, despite claims to the contrary (ASTM, 1990), and those familiar with the issue generally do not expect that an easy solution will be found.

Nevertheless, some progress has been made in AOD in recent years on a scattering problem in F/A-18 windshields. A simple visual test method using a fluorescent ring light has been devised and communicated to the RAAF (Clark, 1995). It appears to make more defects visible than hitherto, including crazing, simply by providing illumination over a larger range of angles than is usual.

5.7 Aircrew Visual Aids

5.7.1 Enhanced Visual Detection

Studies elsewhere of successful wartime fighter pilots indicate that exceptional vision was a common characteristic. Early sighting of opponents presumably gained a tactical advantage. Some way of enhancing the apparent conspicuity of distant aircraft might therefore result in improved effectiveness for our own military fast jets. Increased warning time might also be gained for aircraft collision avoidance.

The Visibility Gauge idea led to a simple prototype of a passive optomechanical vision enhancer in the 1980s, and first indications with a 'bare bones' prototype were that it did work in the right conditions. Small-subtense non-uniformities in luminance, such as distant aircraft projected against a sky background, are made to flicker. The device enhanced conspicuity of near-threshold objects in the peripheral visual field. Further studies are needed to see if the device is likely to be worth the costs of development and the handicap of even a small increase in helmet-mounted mass.

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[8] When the construction of the prototype was requested, ARL was having difficulty in retaining metal workers. The prototype had to be made of wood to avoid a long delay.

5.7.2 Enhancing Aerial Observation

Despite technological advances that have made stand-off weapons highly effective, political constraints in any future conflict may require prior positive visual identification of targets. This is likely to be difficult by day and more so at night. Night Vision Devices (NVDs) might help but they do not seem to be quite good enough at present. Improvements appear possible through ADF-sponsored DSTO tasks on the human factors aspects (as opposed to probability of detection aspects) of NVDs.

In recent years, amateur astronomers have made substantial advances in design, construction and use of low-cost equipment for high-resolution imaging of planetary surfaces. These advances should be exploited for military purposes. Likewise, optical systems for image motion compensation (eg Clark (1978) and current video camera stabilisers) should be pursued to facilitate stabilised telescopic viewing for aerial surveillance and identification.

5.8 Helicopter Clearance Judgement

The Pulfrich Effect is a visual localisation error arising from unequally illuminated eyes viewing objects moving across the field of view. Researching the practical consequences of this led to the realisation that helicopter aircrew views of their own and adjacent main rotors were devoid of most of the usual cues to distance. A half-size model of an Iroquois main rotor was set up in the ARL Vision Laboratory. Results gained with this rig before the laboratory was demolished (by builders, not the rig!) confirmed the difficulties of estimating rotor size (Meehan, Clark and Hughes, 1995) and hence clearance between adjacent helicopters. Some observers reported illusory effects on rotor size. Similar results were obtained with NVGs in use. The findings were presented to Army Aviation, who have a military requirement to operate helicopters in close formation.

5.9 Visual Landing Aids

5.9.1 T-VASIS

Ron Cumming's team also researched ground-based visual landing aids in the 1960s, ultimately leading to the development of T-VASIS and its approval by ICAO for international jet transport operations. Pattern coding was used for the guidance signals, thereby avoiding the likelihood of misinterpretation by colour-vision-deficient aircrew that applies to competing devices (Clark and Gordon, 1979). T-VASIS has light boxes in a row transverse to the runway at the aiming point to provide a datum for glide slope and touchdown position. This can be regarded as the transverse part of a letter T. Light boxes in a line parallel to the runway indicate linear height above or below the correct glide slope. These lights form the stem of the T (upright or inverted), the visible number of lights increasing with departure above or below the glide slope (Figure 2).

Pilots familiar with T-VASIS generally praise it. Most installations are in Australia, but a problem arising is that T-VASIS will come under threat of obsolescence because the colour-coded UK system PAPI is cheaper to install and run. Pressure for withdrawal of ICAO approved status seems likely to increase in future as there is potential for an increasing number of pilots unfamiliar with T-VASIS to confuse the 'on glideslope' signal of T-VASIS with the 'too high' signal of PAPI.

5.9.2 A New Visual Approach Monitor

There is scope for a new system, combining cheapness of installation and operation with intuitively interpretable signals while avoiding the use of primary colour coding. What pilots wish to know is whether their aircraft is actually heading for the intended touchdown point. This can be done with an extra row of high-intensity runway edge lights. Frangible light shields with a horizontal slot in front of each light project vertically narrow fan-shaped beams at a 3° glideslope angle towards the approaching aircraft. Most of the extra lights are visible to approaching aircraft, but only those at and near the achieved aiming point appear brightly. If the light shields extend far enough, the guidance signals can be made visible along the whole of right and left base landing circuit legs.

This new aid has been called VARILAND.[9] It has a 'natural' direct control-display interpretation, and is unlikely to be confused with existing displays. It indicates to the pilot directly where the achieved aim point is relative to the chosen aim point (Figure 2), the same judgements that are otherwise made routinely and unaided by pilots in better lit conditions. Theoretically, it can be made to outperform T-VASIS in quality of information, range and economy. At airports with a pressing demand for movements, such as Sydney Kingsford Smith, it could also reduce runway occupancy time.

Variations on the basic idea are thought possible for use specifically by helicopters, particularly for landing in confined spaces, on ships and on oil rigs, and in cities. However, progress has been blocked for several years because no authority in Australia has been prepared to support even the most minimal full scale demonstration.

5.10 Discussion

DSTO capabilities in dealing with operational issues in aircrew vision have developed over the three decades that the writer has represented Defence in Standards Australia committees and two decades in Working Parties 10 and 61 of the Air Standardization Coordinating Committee (ASCC). Occasional interaction has taken place with the American National Standards Institute (ANSI) and the International Standards Organisation (ISO). Specific topics at issue have included sunglasses, motor cyclists' visors, eye protection against optical radiation (as in welding filters), and the optical properties of land vehicle transparencies. Although these topics are largely civil in their applications, involvement has been an essential part of improving performance in the military context. The scientific literature and user experience base for these items in their civil applications vastly outweighs the military equivalents, and the benefits of their study have been substantial both for Australian Defence, and in turn that of our allies through ASCC. The point being made is that dealing adequately with aircrew vision handicaps demands a much broader approach than one confined merely to military aspects and experience. The nugatory results of some of the contract military

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[9] An objection to this name is the ease of corruption to Fairy Land. However, there are many similarly irreverent corruptions that, if anything, have assisted rather than harmed acceptance of the particular devices or processes concerned.

R&D done on aircrew vision in other countries demonstrate this point starkly. The need for a broadly based approach to aircrew vision problems will not disappear following the writer's retirement!

5.11 Conclusion

The complexity of the human visual system and the associated difficulty of solving the problems involved in interfacing visual and military aircraft systems appears to justify a longer-term commitment and broader approach than in many other specialist areas of science and technology support to Defence. Although the proportion of DSTO resources committed to this area has been minuscule to date, the military value of enhanced aircrew visual performance and reduced visual handicaps should be sufficient to justify a substantially larger effort, even in a time of shrinking overall resources.

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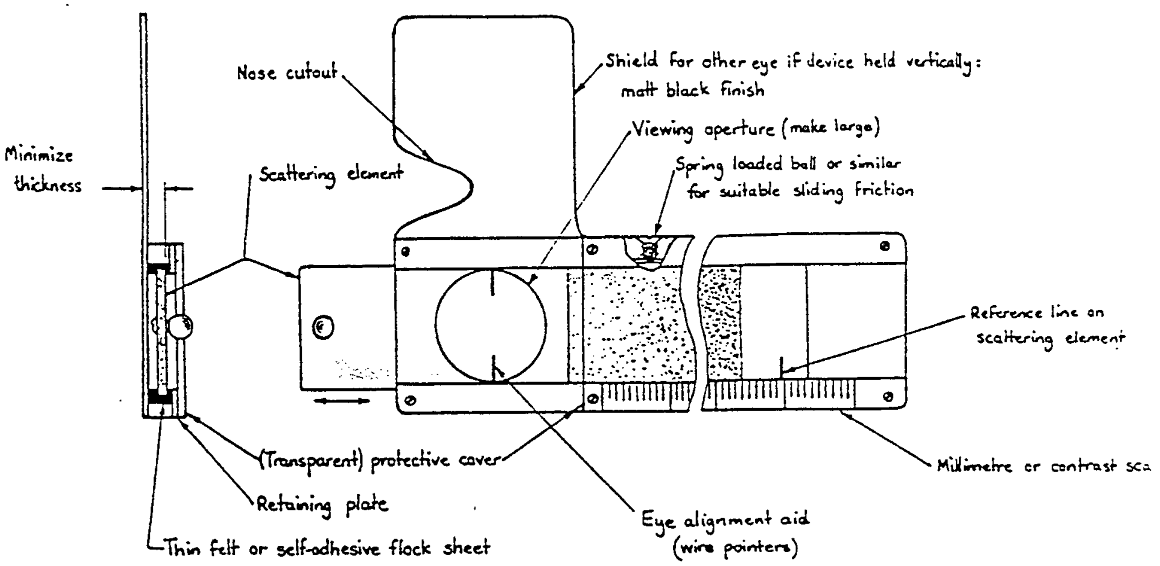

Figure 1. The Visibility Gauge (from Clark, 1985).

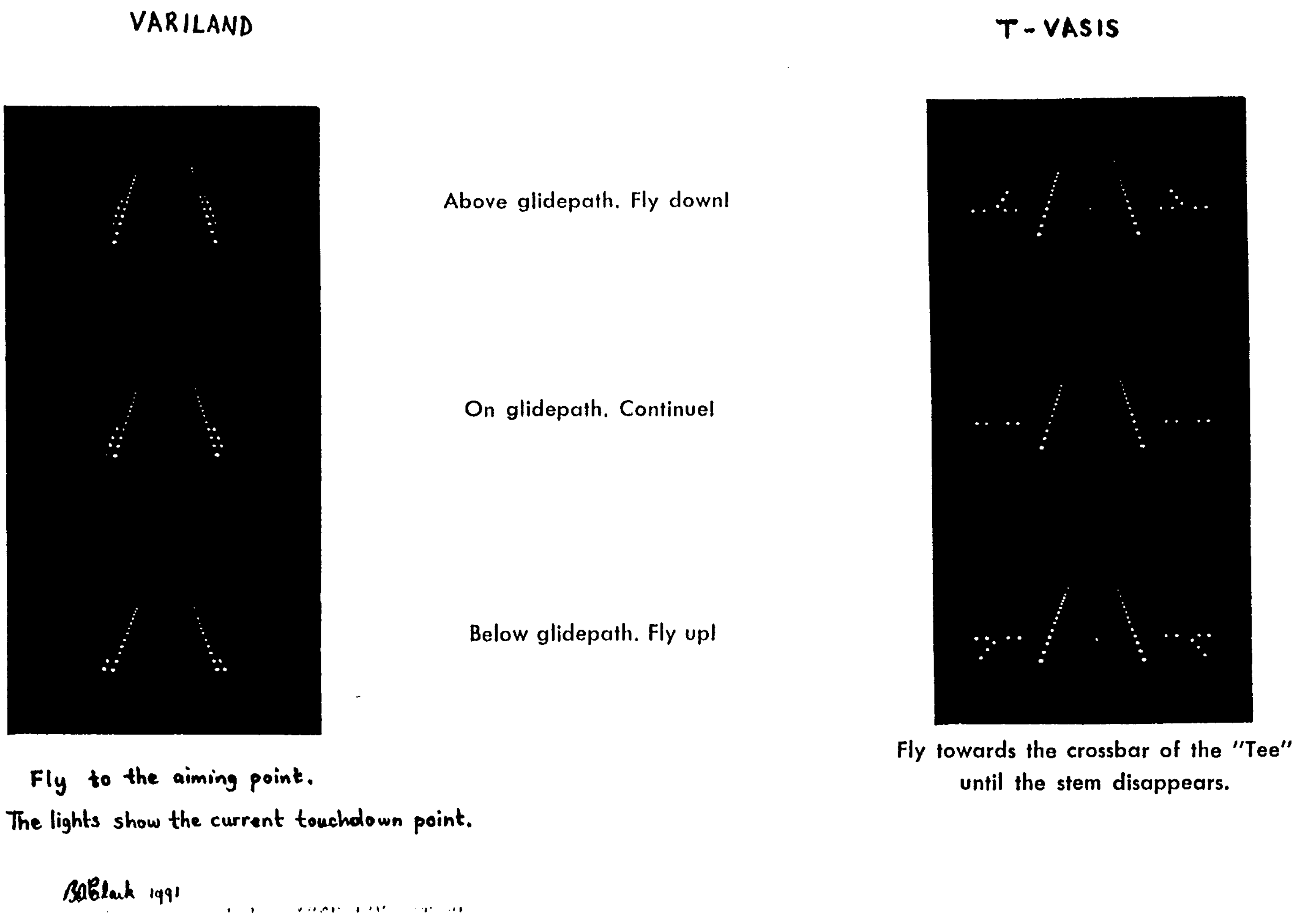

Figure 2. VARILAND and T-VASIS landing aids.

6. Influences on my Career in Defence Science

Barry A. J. Clark, Air Operations Division, AMRL

6.1 Education

At age 7, I was impressed by Spitfires in a WW2 victory flight over Melbourne suburban rooftops. In the following years, model aircraft, Meccano and encyclopedias (not to mention joke books) provided relief from schools where discipline was often harsh. Undiagnosed mild myopia accentuated the discovery that sharp distance vision was available through binoculars and telescopes. My first homebuilt telescope provided some hard lessons, especially when the eyepiece assembly fell inside the tube and smashed the singlet objective that had cost weeks of pay from a paper round.

My goal at Junior Technical School was a railways apprenticeship but Commonwealth Scholarships allowed completion of a Mechanical Engineering Diploma at Footscray Senior Technical School by 1957. I was also an amateur telescope maker, a demonstrator at the old Melbourne Observatory, a member of the Air Training Corps (and thereby an official at the 1956 Melbourne Olympics) and then the Citizen Air Force, and had a few seasons as a field umpire in junior Australian football. Interests in solar-terrestrial relations and long-range weather forecasting and the financial support of a Dafydd Lewis Scholarship led to a physics course at the University of Melbourne, but the consequence of too much time on astronomy was rather ordinary academic results. During vacations in 1957 to 1959, voluntary and paid work in the optics laboratory of Physics Division at Defence Standards Laboratory in Maribyrnong was like being in paradise. Full time work there began in November 1959.

In 1962, the part-time lecturer in optics at the Victorian College of Optometry resigned at short notice, and I gained the position as the only available optics professional. Experimental Officers, especially at base grade, were neither expected nor encouraged to do research and report it, but the incorporation of optometry into the new Faculty of Applied Science at the University of Melbourne provided an opportunity to do a masters degree at DSL within an allocation of 10% of work time. Topographical measurements of human corneas were and still are of interest: at the time it was for hard contact lens fitting. A large lens assembly retrieved from a laboratory rubbish bin during a cleanup was identified as from a sphericity interferometer developed during WW2 for steel bearing balls. (Its excellent design was by Gus Schaeffer, who later founded military operational research in Australia.) Interferometric observation of corneas with this lens was only partially successful, but an alternative geometrical optics approach worked well. A Commonwealth Public Service Board Scholarship then provided two years of full time study leave for quantitative application of the technique, with PhD awarded in 1972. The Defence justification was the potential for contact lenses to keep pilots flying when they required refractive correction.

6.2 A Technical Motivator

Observations of solar activity are more revealing if made only in light emitted by particular atomic transitions of hydrogen or calcium. Technically this is difficult and expensive, requiring high spectral dispersion in a telescope-monochromator combination, or filters with extremely narrow pass bands (< 0.1 nm) in a specialised telescope. This instrumental optics problem (still with me after forty years!) motivated my interest in spectral characteristics of materials and colour filters, topics also having many Defence applications such as the specification of spectral properties of aircrew sunglasses and visors, and the external and internal surface finishes and lighting of aircraft, vehicles and ships.

6.3 Aviation at Last!

Myopia had thwarted an attempt at a military flying career, but I contributed to the visual aspects of a crash investigation for the Department of Civil Aviation while on study leave. I returned to DSL in 1970 and worked on camouflage until transferring to Aeronautical Research Laboratories for the resumption of human engineering there. One of the attractions offered at ARL was civil flying training, but six years of paper warfare passed before it actually began. In the meantime I took up gliding, an activity that has continued to assist my interaction with military aviators. However, it has also been too enjoyable to justify official funding!

6.4 Policies and Politics

Human factors work at Fishermens Bend has always served Defence very well indeed in my view, but as a so called soft science it seems to have attracted more than its share of political attention. For instance, human factors, along with operations research, came close to being abolished as a DSTO activity in the mid 1980s, and the adverse effects on staff morale, loyalty and output were costly to Defence for several years after. Since the work began in the 1950s, overall policy has fluctuated between discouraging and promoting interaction of the human factors area with medical and non-aviation parts of the ADF, with civil aviation and with other non-Defence areas, and most of these changes of direction have been costly.

Across Defence Science, scientific and technological knowledge and excellence of individual researchers was once regarded as not subject to any upper limits, but recent years have brought increasing pressure on the more successful scientists to take up managerial functions, thereby tending to limit 'hands on' achievements. Competent technical managers are essential, of course, but keeping up a supply pool generally removes the more innovative scientists from their own specialist support of Defence and the associated direct coaching role. Attempts to compensate by directing subordinates to be more innovative are arguably futile. Doubtless the corporate activities that I worked on have been of value, but they also contributed substantially to delays in necessarily long-term research on the fidelity of flight simulation, helicopter rotor clearance perception, NVGs illusions and human factors aspects of helicopter separation monitors.

My last months with DSTO have largely been concerned with the Black Hawks mid-air collision of June 1996. Although this work drew on a remarkably large part of my career experience, the challenge it offered was tempered by the tragic consequences of the accident.

6.5 The Future

My avocational research on weather as an astrophysical phenomenon has progressed far in forty years, particularly since microcomputers have become available and are now powerful enough for the analyses to be conducted in manageable run times (days and weeks!). I plan to continue this project as my main retirement activity. I also expect to complete the revision of several journal papers. I have enjoyed the opportunity to contribute to the defence of Australia through DSTO, and my early retirement provides the opportunity to continue contributing, albeit in my own way.

6.6 Employment History

1991 to 1996	Senior Principal Research Scientist, Aircraft Systems/Air Operations Division AMRL
1993 to 1996	Research Leader, Human Factors
1991 to 1993	Research Leader, Advanced Technology
1979 to 1990	Principal Research Scientist, Human Factors Group, Systems Division, ARL
1971 to 1979	Senior Research Scientist, Cybernetics Group, Systems Division, ARL
1970 to 1971	Acting Exp. Officer Grade 3, Applied Research (Physics) Group, Physics Division, Defence Standards Laboratories
1963 to 1970	Experimental Officer Gr 2, Chemical Physics and Optics Group, DSL
1959 to 1963	Experimental Officer Gr 1, CP&O Group, DSL
1957 to 1959 (part)	Technical Assistant Gr 2, Optics Group, DSL
1962 to 1972	Part-time lecturer in Physical Optics, Geometrical Optics and Physiological Optics, Department of Optometry, University of Melbourne

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19. ABSTRACT

This report contains written versions of selected presentations given at a Festschrift for Dr Barry Clark on 7 November 1996. The Festschrift marked the occasion of Barry's retirement and provided a forum to discuss some the work he had conducted during his career and also to discuss ongoing work in Air Operations Division.