Perceived Pilot Workload and Perceived Safety of Australian RNAV (GNSS) Approaches

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On 7 May 2005, the crew of a Metro 23 aircraft were conducting the Lockhart River runway 12 RNAV (GNSS) approach when the aircraft collided with terrain in IMC, fatally injuring all 15 on-board. As part of the investigation into this accident, Australian civilian pilots with an RNAV (GNSS) endorsement were mailed a survey asking them to assess perceived workload, situational awareness, and safety on a number of different approach types. Responses from 748 pilots (22%) were received and analysed based on the aircraft performance category. For pilots operating Cat A and B aircraft (predominantly single and twin-engine propeller aircraft), the RNAV (GNSS) approach resulted in the highest perceived pilot workload, more frequent losses of situational awareness, and the lowest perceived safety compared with all other approaches evaluated apart from the NDB approach. For pilots operating Cat C aircraft (predominantly high capacity jet airliners), the RNAV (GNSS) approach only presented higher perceived pilot workload and less perceived safety than the precision ILS and visual day approaches, but lower workload and higher safety than the other approaches evaluated. The different aircraft category responses were likely to have been due to high capacity aircraft having advanced automation capabilities and operating mostly in controlled airspace. The most common concern raised by respondents was that RNAV (GNSS) approaches did not reference distances to the missed approach point on the approach chart and cockpit displays. Other problems raised involved short and irregular segment distances and multiple minimum segment altitude steps, and that five letter long waypoint names differing only by the last letter can easily be misread.

Area navigation (RNAV) global navigation satellite system (GNSS) approaches are a type of non-precision instrument approach procedure. Formally known as global satellite system non-precision approaches (GPS/NPA), RNAV (GNSS) approaches are relatively new, both in Australia and internationally, with the first approaches designed in 1996-97. By 2006, over 400 RNAV (GNSS) approaches had been published for aerodromes across Australia and their use had become common among instrument-rated pilots of a range of aircraft from piston engine aircraft to high capacity jet airliners.

RNAV (GNSS) approaches provide pilots with lateral guidance based on (generally five) waypoints. These waypoints are published latitude and longitude positions (given a five letter name) in space that are pre-programmed into a global positioning system (GPS) receiver or a flight management system (FMS). During the approach, the GPS/FMS displays to the pilot(s) each leg as a track and distance to the next waypoint in the approach sequence. From that information, the pilot must determine what altitude to descend to, based on altitudes published in the approach chart. Like other non-precision approaches, there is no altitude guidance. Unlike a distance measuring equipment (DME) display, there is no distance display on GPS receivers, nor on the distance/altitude table of approach charts, that provides a continuous distance reference to the runway. This has the potential to greatly increase pilot workload (due to the mental calculations needed to determine distance form the runway) and reduce situational awareness (due to not having ready access to the aircraft's location relative to the runway) compared to non-precision approaches referencing a DME.

Waypoints generally have five alphanumeric characters. In Australia, all characters are capital letters. The first four letters of each waypoint remains the same within an approach, and represent the three letter aerodrome identifier (e.g. LHR for Lockhart River), and the direction travelled from during the final approach (e.g. W for west). Only the fifth letter in the waypoint name varies to identify which waypoint the aircraft is approaching. By concealing the one letter that identifies the waypoint position at the end of the waypoint name and among other capital letters increases the potential for a waypoint to be misread during an approach. This is especially likely under high workload conditions and/or due to an expectancy error if the pilot is confused about the aircraft's location, and would result in reduced situational awareness.

The international standard for an RNAV (GNSS), as described in the International Civil Aviation Organization (ICAO) Pans/Ops document 8168, is for an optimum distance of 5 nm between waypoints for the initial and final segments. The Pans/Ops also requires the profile descent path to have an angle of no greater than 3.5 degrees (6.1%) for Cat C and D aircraft, and 3.77 degrees (6.5%) for Cat A and B aircraft, with an optimum slope of 3 degrees. A further Pans/Ops requirement for RNAV (GNSS) approaches is for the final approach path to be aligned within 20 degrees of the runway for Cat A and Cat B aircraft and within 15 degrees for Cat C and Cat D aircraft. This criterion eliminates the need to conduct a circling approach. Complications can arise when designing to Pans/Ops optimum standards due to obstacle clearance requirements. As a result, distances between the waypoints can vary from 5 nm, the slope can be steeper than 3 degrees, and multiple minimum segment altitudes between each pair of waypoints can be needed to maintain appropriate obstacle clearance. These more sub-optimal approach designs could be expected to increase pilot workload during an approach due to additional steps to monitor and due to more complicated mental calculations required to determine the aircraft's distance from the runway.

Goteman and Dekker (2003) investigated navigation accuracy and pilot workload for RNAV (GNSS) and ILS approaches using airline pilots operating Boeing 737 NG aircraft equipped with LNAV and barometric VNAV[1] with the autopilot on. The study found good tracking accuracy and low pilot workload based on subjective workload assessments completed at the end of the flight. Compared with other non-precision approaches, the low workload assessments and higher pilot acceptance of RNAV (GNSS) approaches were reported as being due to the change from a cognitive task (calculating vertical position) to a perceptual task (matching the constant angle approach path with the aircraft's position). VNAV capability is generally limited to high capacity airliners in Australia.

Research objectives

Due to the relatively recent introduction of RNAV (GNSS) approaches, very little accident and incident data are available concerning them. However, the Australian Transport Safety Bureau (2006a, 2006b) has recently investigated two high profile accidents where the pilots were conducting an RNAV (GNSS) approach, including the Metro 23 VH-TFU that impacted terrain on the Lockhart River Runway 12 RNAV (GNSS) approach on 7 May 2005, killing all 15 people on board. The objective of this research project was to gain an understanding of the experiences and perceptions of RNAV (GNSS) approaches in Australia from pilots who are currently using these approaches. Specific objectives were to understand pilot perceptions of:

- pilot workload during an RNAV (GNSS) approach;
- ability to maintain situational awareness during an RNAV (GNSS) approach; and
- how safe RNAV (GNSS) approaches are.

Method

Respondents

A survey was mailed to all Australian pilots with an RNAV (GNSS) approach endorsement on their instrument rating. There were 748 surveys completed and returned to the ATSB, a response rate of 22%. Survey responses were received from individuals representing a broad range of pilot

[1] VNAV refers to vertical navigation capability, also known as managed descent.

licence holders (private to airline), covering a variety of aircraft types. Respondents were placed in groups based on the main aircraft they operated using aircraft performance categories[2] A, B, and C. There was a wide range of aircraft included in Cat A (145 respondents), which were comprised predominantly single-engine aircraft and small twin-engine aircraft. Cat B (271 respondents) also had respondents operating a range of aircraft which can the described as mostly larger twin-engine propeller aircraft, both piston and turbine. Of these aircraft, the most common were de Havilland Dash 8 aircraft representing 23% of respondents, King Air aircraft (20%), and SAAB 340 aircraft (16%). In contrast, Cat C aircraft (231 respondents) were predominantly high capacity regular public transport jet aircraft and mostly Boeing 737 aircraft (79%). The relatively small number of responses (42) from helicopter pilots (Cat H) did not allow for reliable statistical analysis of responses within this group.

As with all surveys using a sample of a total population, the results below represent an estimate of the population of RNAV (GNSS) endorsed pilots, rather than exact measure of that population. Statistical tests used to determine whether differences exist take into account the number of respondents within each group as well as the variation between respondents within each group.

Survey Design

Part 1 of the survey asked pilots to assess a number of dimensions for the following approaches: Visual (Day); Visual (Night); ILS; DME Arrival; VOR/DME approach; NDB approach; and RNAV (GNSS) approach.

The approaches were assessed on seven Likert scales including pilot workload, situational awareness, and safety[3]. The dimensions for pilot workload were mental workload, physical workload, and time pressure, which were taken from Hart and Staveland's (1988) NASA-TLX subjective workload index. The assessments for each dimension were completed for all approaches together so that the respondent could record relative values.

Part 2 of the survey involved open-ended answers to questions specifically dealing with the RNAV (GNSS) approach. Respondents were asked to write which aspects of the RNAV (GNSS) approach contributed to five of the dimensions assessed in Part 1. Separately, they were asked to indicate if any aspects of the RNAV (GNSS) approach could be improved. Part 3 of the survey involved pilot experience, both in general and for each approach type specifically. It also asked respondents to indicate their main method of flying each approach, either using autopilot or by hand-flying, and whether they conducted each approach mainly inside controlled airspace (CTA) or outside of controlled airspace (OCTA).

Data analysis

Part 1 of the survey was analysed using the inferential statistical technique of analysis of variance (ANOVA) using a mixed model (both between-subjects independent variables and a repeated measures factor). The repeated measures factor was always the approach type. Simple repeated measures contrasts were used to compare the assessments for each approach with the RNAV (GNSS) approach. Several between-subjects variables were analysed in separate ANOVAs. However, only results based on aircraft performance category are presented in this paper. Between-subjects variables were analysed using planned orthogonal contrasts.

The differences in the number of respondents indicating autopilot use and airspace for each approach were analysed using a chi-square analysis.

Bivariate correlations (Pearson's coefficient using two-tailed test for significance) were conducted between the assessments given for each approach and the following: total hours; total

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[2] Aircraft performance categories are determined by multiplying the aircraft's stall speed in the approach configuration by a factor of 1.3.

[3] A seven point Likert scale was used for all dimensions (*easy* to *high*) except situational awareness which used a four point Likert scale (*never*, *only once*, *sometimes*, and *often*).

hours in the last 90 days; total instrument hours; total instrument hours in the last 90 days; number of approaches (of that type) conducted per year; and number of years the endorsement for that approach had been held.

All data analyses used a type 1 error rate of 1% ($\alpha \leq .01$). Statistical results are reported below using probability levels only.

Results

Type of approach

Workload. The RNAV (GNSS) approach was assessed as requiring more pilot workload on each scale (mental workload, physical workload, and time pressure), than each of the other approaches ($p<.001$) except for the NDB approach (Figure 1). There were no statistically significant differences between the NDB and RNAV (GNSS) assessments for mental workload and time pressure. However, for the physical workload scale, the RNAV (GNSS) approach was assessed as having less physical workload than the NDB approach ($p<.001$).

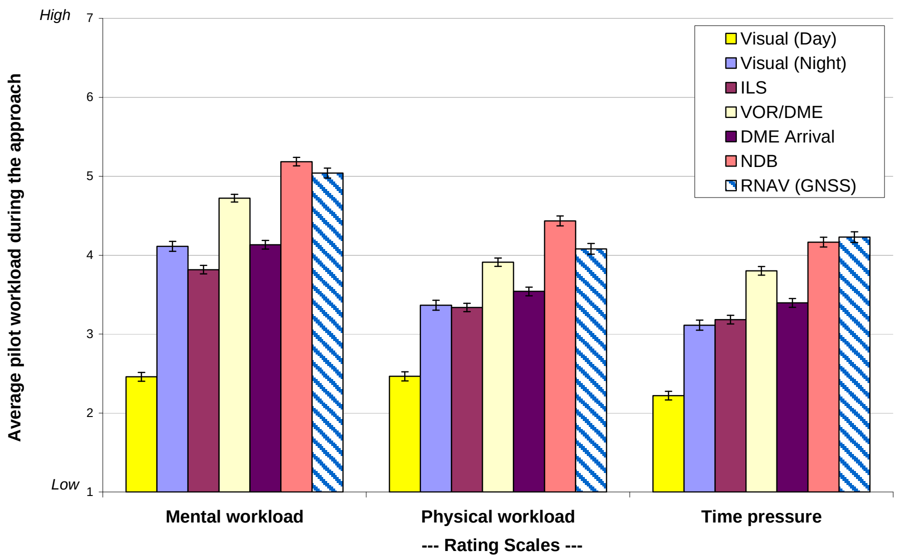

Figure 1: Mean (±1 SEM)[4] pilot workload assessments

Situational Awareness. Respondents indicated they have had trouble maintaining situational awareness more often on the RNAV (GNSS) approach than each of the other approaches ($p<.001$) except for the NDB approach. The assessments for the NDB and RNAV (GNSS) approaches were not statistically different.

Perceived Safety. The average safety assessments indicated the RNAV (GNSS) approach was perceived as being more dangerous than each of the other approaches ($p<.001$) except the visual (night) and NDB approaches. There were no differences in the safety assessments between the RNAV (GNSS) approach and the visual (night) approach. However, the NDB approach was assessed as significantly more dangerous than the RNAV (GNSS) approach ($p<.001$).

Aircraft Performance Categories

4 Standard error of the mean is shown by the error bars.

Workload. The pilot workload assessments (averaged across mental workload, physical workload, and time pressure) from Cat A and Cat B aircraft indicated the RNAV (GNSS) approach was more difficult than the other approaches, except the NDB. However, pilots from the faster Cat C aircraft assessed the other approaches (with the exception of visual (day) and ILS) as involving higher workload levels than the RNAV (GNSS) approach. This led to significant interactions between Cat A and B aircraft and Cat C aircraft and between the RNAV (GNSS) approach and all other approaches (p<.001) except with the ILS. The RNAV (GNSS) approach was similarly assessed as more difficult than the ILS by both groups of respondents.

The only two approach types which received different assessments from pilots from Cat A aircraft and Cat B aircraft were the ILS and RNAV (GNSS) approach. Cat B (larger twin-engine propeller) aircraft pilots assessed the RNAV (GNSS) approach as more difficult than pilots from the slower Cat A (single engine and smaller twin-engine) aircraft, but the ILS approach as less difficult, leading to a significant interaction (p<.001).

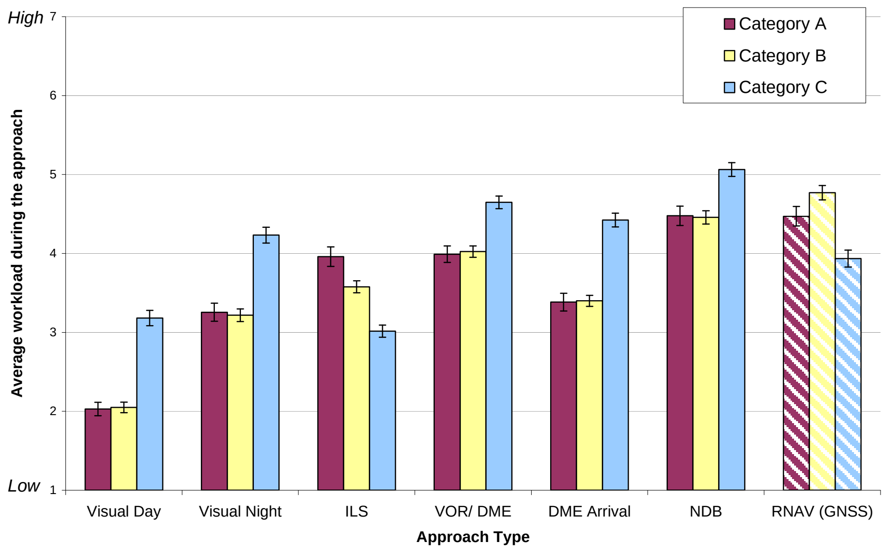

Figure 2: Mean (±1 SEM) pilot workload assessments for aircraft performance categories

Situational Awareness. For Cat A and Cat B aircraft pilots, the average number of reported loss of situational awareness experiences on the RNAV (GNSS) approach was higher than on all other approach types except the NDB. In contrast, loss of situational awareness experiences for Cat C aircraft pilots was more similar on other approach types (other than the ILS) to the RNAV (GNSS) approach (Figure 3). This led to significant interactions between the RNAV (GNSS) approach and the other approaches (p<.001) except the ILS between Cat A and B aircraft and Cat C aircraft.

The Cat B aircraft pilots indicated they had lost situational awareness on the RNAV (GNSS) approach more often than the other approaches to a greater extent than pilots from the slower Cat A aircraft. However, this interaction was only statistically significant compared with the visual (night) approach (p<.01).

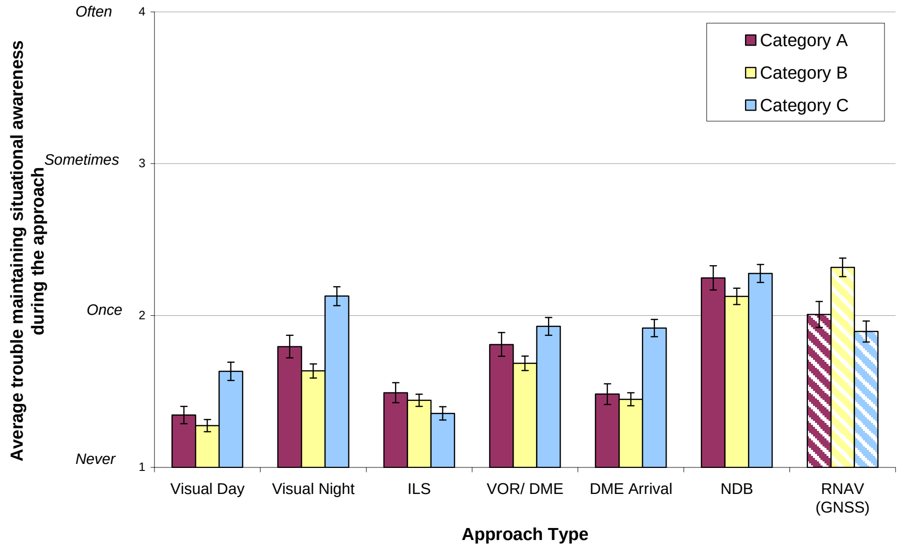

Figure 3: Mean (±1 SEM) situational awareness loss assessments by aircraft performance categories

Perceived Safety. As can be seen in Figure 4, that the RNAV (GNSS) approach was assessed as less safe than the visual (day) approach by the Cat C aircraft pilots, but to a lesser extent than from pilots from the slower Cat A and Cat B aircraft ($p<.001$). In addition, the RNAV (GNSS) approach was assessed as safer than the remaining approaches (except ILS) by Cat C aircraft pilots, but only the NDB approach was assessed as less safe than the RNAV (GNSS) approach by the pilots of the slower aircraft categories ($p<.001$). There was also a significant interaction with the NDB approach due to more extreme NDB assessments (in terms of being less safe) over the RNAV (GNSS) approach for the Cat C aircraft pilots than from Cat A and B aircraft pilots.

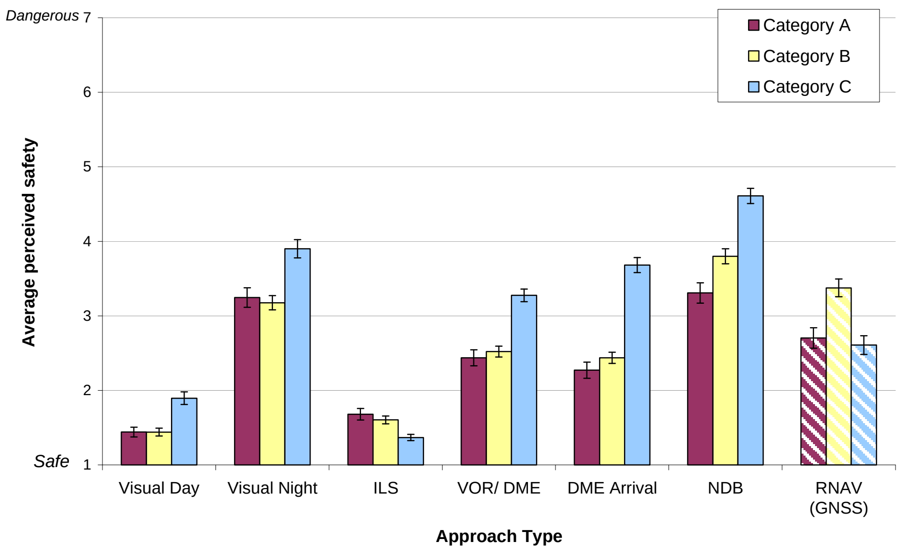

Figure 4: Mean (±1 SEM) perceived safety for the approach by aircraft performance

Aspects of an RNAV approach that contribute to pilot workload & safety

Mental Workload. When asked to state which aspects of the RNAV (GNSS) approach contributed to mental workload, 123 respondents (20.8% of those answering this question) included the fact that the GPS receiver or FMS and/or approach chart do not reference distances to the missed approach point. A further 92 respondents noted that the mental workload was related to maintaining an awareness of the aircraft's position and altitude throughout the approach. Another common response (13%) included the amount of programming needed for the FMS or GPS before an approach. The most common approach design related response (13%) involved irregular segment lengths and/or many close steps which increased workload, or conversely, an optimum design with 5 nm segments that reduced workload. Reading and interpreting the approach chart was also mentioned by 10% of respondents

Physical Workload. The most common contributions to physical workload were setting up the approach on the FMS or GPS (16%), and manipulation of the FMS or GPS (11%). Configuring the aircraft (setting flaps and landing gear to the appropriate positions) late in the approach increased physical workload and conversely, configuring the aircraft for landing early in the approach was listed as helping reduce physical workload (9%). The main issue that reduced physical workload was the use of automation (13%). This was most commonly listed by Cat C aircraft pilots (28%). An additional 11% of Cat C aircraft pilots listed VNAV as reducing workload. Cat C aircraft respondents to this survey were mostly from high capacity jet airliners.

Time Pressure. The most common aspect listed as increasing time pressure during an approach was irregular segment lengths and/or many altitude limiting steps (19% of all respondents), especially for Cat A (24%) and Cat B (25%) pilots from single and twin-engine propeller aircraft. For the Cat C pilots, receiving a late clearance from air traffic control (ATC) to fly an approach was the most common aspect leading to time pressure (20%), followed by late configuration of the aircraft (15%), briefing requirements (13%), and FMS programming requirements (10%). Briefing requirements were not listed as increasing time pressure at all for Cat A aircraft pilots and by very few Cat B aircraft pilots.

Perceived Safety. The most common reasons that influenced respondents' perceptions of lower RNAV (GNSS) approach safety were the lack of distance to the missed approach point (MAP) information (14%) and not being able to ensure situational awareness (12%). In contrast, the runway alignment of RNAV (GNSS) approaches was seen as a positive contribution towards safety by 30% of respondents. Cat C aircraft pilots also indicated that automation and VNAV in particular improved the safety of RNAV (GNSS) approaches (14%). Pilots from this category also commented that maintaining a constant profile down to the MAP also improved safety (9%).

Correlations between workload assessments and experience and recency levels

The number of years since respondents' RNAV (GNSS) rating were gained was significantly and positively correlated with the time pressure experienced during an RNAV (GNSS) approach ($p<.01$). That is, the longer a respondent had held an RNAV (GNSS) rating, the more likely it was that their time pressure estimates for the RNAV (GNSS) approach were higher. This was the only statistically significant correlation for the RNAV (GNSS) workload assessments.

In contrast, the mental workload, physical workload, and time pressure assessments on the ILS approach were negatively correlated with total hours experience, total instrument hours experience, the number of ILS approaches per year, and years the pilot had held an ILS rating ($p<.001$). That is, the more experience a pilot had with ILS approaches, the lower was their workload assessment.

Mental workload, physical workload, and time pressure assessments for the NDB approach were negatively correlated with the number of years the pilot held an NDB rating ($p<.01$), and mental workload was also negatively correlated with total flying experience ($p<.01$). The time pressure assessments on the DME arrival were negatively correlated with the number of DME arrivals completed each year.

Autopilot

The majority of respondents from Cat A (typically small single and twin-engine aircraft) operated every approach by hand-flying ($p<.001$). In contrast, the only approaches with more respondents hand flying for Cat B aircraft (generally larger twin-engine propeller aircraft) were the visual (day) approach ($p<.001$) and NDB ($p<.01$). The VOR/DME had the same proportion of Cat B aircraft pilots' hand-flying and using autopilot, while all other approaches, including the RNAV (GNSS) approach, had slightly more pilots using an autopilot (ranging from 62 to 69%). Cat C aircraft pilots (predominantly from high capacity jet airliners) had over 87% of all pilots using an autopilot on each instrument approach ($p<.001$), but had 83% of pilots hand-flying visual (day) approaches ($p<.001$). The visual (night) approaches had about equal proportion of Cat C aircraft pilots using an autopilot and hand-flying.

Airspace

The majority of RNAV (GNSS) approaches were conducted outside controlled airspace by the Cat A and Cat B aircraft (79 and 78% respectively), ($p<.001$). However, most (75%) respondents from the high capacity jet dominated Cat C conducted RNAV (GNSS) approaches mostly in controlled airspace ($p<.001$).

Improvements

The majority (82%) of respondents indicated that they thought aspects of the RNAV (GNSS) approach could be improved. This proportion was similar across aircraft performance categories.

The most common improvement response (40% of respondents) involved making reference to the distance to run to the MAP on both the approach charts and the GPS/FMS, rather than only including distance to the next waypoint. Similarly, another 7% indicated the FAF could be removed, essentially giving distance to run to the MAP from the intermediate fix.

Many respondents also indicated that the naming convention of waypoints should be changed to minimise the chance of misreading a waypoint and subsequently losing situational awareness. The main issue arising involved the use of five-letter waypoints with only the final letter differing for each waypoint within an approach.

Using the Pans/Ops optimum design criteria for all RNAV (GNSS) approaches and removing short and intermediate altitude restriction steps was also a common improvement suggestion. The most common approach design improvement was for lower minimas, while the main air traffic control improvement (mostly from Cat C aircraft pilots) was to connect standard terminal arrival routes (STARs) with the commencement of RNAV (GNSS) approaches.

The most common aircraft capability improvement listed was vertical guidance (such as VNAV). This response was the most frequent for Cat B aircraft pilots (9.2%).

Discussion

For pilots operating Cat A and B aircraft (generally single and twin-engine propeller aircraft), the RNAV (GNSS) approach resulted in the highest perceived pilot workload (mental workload, physical workload, and time pressure), reported loss of situational awareness more frequently, and the lowest perceived safety compared with all approaches evaluated apart from the NDB approach. For pilots operating Cat C aircraft, mostly Boeing 737 and other high capacity regular public transport aircraft, the RNAV (GNSS) approach only presented higher pilot workload and lower perceived safety than the precision ILS and visual day approaches.

The differences between the responses from pilots from Cat C aircraft and those from the slower Cat A and B aircraft were likely to be due to differences in aircraft equipment, airspace (controlled or uncontrolled), and possibly the differences in crew and training and procedures, particularly regarding briefing prior to commencing the approach. Cat C aircraft were generally operated on RNAV (GNSS) approaches using an autopilot with VNAV. This significantly reduces the pilot's cognitive requirements for calculating the descent profile and changes the flying task to a perceptual task of reducing descent angle error, significantly reducing pilot workload while maintaining or increasing vertical and lateral navigation accuracy. Ninety-one percent of responses from Cat C pilots indicated that they used automation for RNAV (GNSS) approaches, which they also identified reduced physical workload and increased safety. The second difference is that RNAV (GNSS) approaches were mostly conducted in controlled airspace for Cat C, but OCTA for Cat A and Cat B aircraft. Further, OCTA was found to increase workload levels (for Cat B aircraft and Cat C aircraft pilots), placing additional pressures on pilots during an already difficult approach. More detailed approach briefings and company approach procedures in high capacity airlines probably also contributed to the differences found.

The concern that most respondents had about the design of RNAV (GNSS) approaches was that they do not use references for distance to the missed approach point (MAP) on the approach chart and GPS/FMS display. This response was common from respondents in all types of aircraft categories, and was listed as affecting all areas of the survey, including all aspects of pilot workload and perceived safety, and was the most common improvement suggested by respondents. The RNAV (GNSS) approach is the only instrument approach where the reference point for distance information changes during the approach. The data are technically available to display distance to the MAP information, but electronic displays must be modified to allow this. Approach chart altitude-distance tables could also be modified easily to display this information more clearly.

Short and irregular segment distances, and multiple minimum segment altitude steps were also identified as a major concern by many pilots using RNAV (GNSS) approaches. These were the most commonly listed reasons given by pilots for increased time pressure, and were frequently cited as factors that increased physical and mental workload and reduced safety. Approaches with these features represent the minority (20%) of RNAV (GNSS) approaches in Australia. Although these approaches meet the basic ICAO Pans/Ops requirements, the results of this survey suggest that increased pilot workload and the increased potential to lose situational awareness also needs to be considered before publishing such approaches. When they are published, pilots need to include in their approach briefings the potential for such designs to increase workload.

The naming convention of using five capital letters for waypoint names with only the final letter differing within an approach, was reported to not only cause clutter on the charts and GPS and FMS displays, it was also reported as increasing the chance of a pilot misinterpreting a waypoint, especially under high workloads and in adverse weather conditions.

The findings of this research only represent subjective assessments of workload, situational awareness, and safety, of RNAV (GNSS) approaches. Future research that investigates objective measures of workload, situational awareness, and safety, in realistic flying conditions such as a flight simulator, would be useful to confirm the current results.

The findings of the above research suggests that the current standards for GPS and FMS displays concerning distance references, and the approach charts that replicate this information, add to pilot workload and reduce situational awareness due to the mental calculations required by pilots to determine the aircraft's location relative to the runway. These calculations are made more difficult when terrain necessitates an approach design other than the usual 5 nm segments. Finally, the current waypoint naming system used in Australia increases the chance of pilots misreading a waypoint, especially given the workload levels reported in this research. Therefore, the current findings suggest that the changing distance references and current waypoint naming practices may not represent the best safety practice possible.

Safety Actions

Airservices Australia

Aviation safety will be enhanced considerably if regional airlines, charter operators and general aviation users can be provided with vertical guidance during area navigation global navigation satellite system (RNAV (GNSS)) approaches, complementing the accurate track information and straight-in approaches already available from GNSS. The Australian Transport Safety Bureau (ATSB) has been advised that the board of directors of Airservices Australia has endorsed the ground based regional augmentation system (GRAS) for Australia, with the intention that it becomes operational from 2009, subject to certification by the Civil Aviation Safety Authority.

The ATSB regards the introduction of a vertical navigation capability for area navigation global navigation satellite system (RNAV (GNSS)) approaches as a high priority, particularly as it is likely to offer the highest safety benefit for the widest number of users. The ATSB will monitor the progress of approach with vertical guidance (APV) implementation.

Civil Aviation Safety Authority

The ATSB notes the Civil Aviation Safety Authority's (CASA) intention to have the findings of this report considered by the Australian Strategic Air Traffic Management Group (ASTRA) for the purpose of identifying opportunities to improve current practices. The ATSB will monitor the outcomes of this group's advice.

The ATSB notes CASA's intention to review the findings of this report and consult with regulators overseas and review research findings from other studies. The ATSB will monitor the outcomes of this process.

Recommendations

A range of recommendations were given to CASA and Airservices concerning the workload and situational awareness findings concerning RNAV (GNSS) approaches, RNAV (GNSS) approach chart design, sub-optimal RNAV (GNSS) approach designs, waypoint naming convention, and late clearances from air traffic controllers to conduct RNAV (GNSS) approaches (see Recommendations R20060019 – R20060024 on the ATSB internet site <www.atsb.gov.au>).

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Further Information

This paper provides a summary of this research. For the full details of the results, including additional topics for which the survey covered can be found in:

Godley, S. T. (2006). *Perceived Pilot Workload and Safety of RNAV (GNSS) Approaches* (Aviation Research Report B2005/0342). Canberra: Australian Transport Safety Bureau. <http://www.atsb.gov.au/publications/2006/20050342_RNAV.aspx>.