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THE AIRLINE PILOT'S VIEW OF FLIGHT DECK WORKLOAD: A PRELIMINARY--ETC(U)

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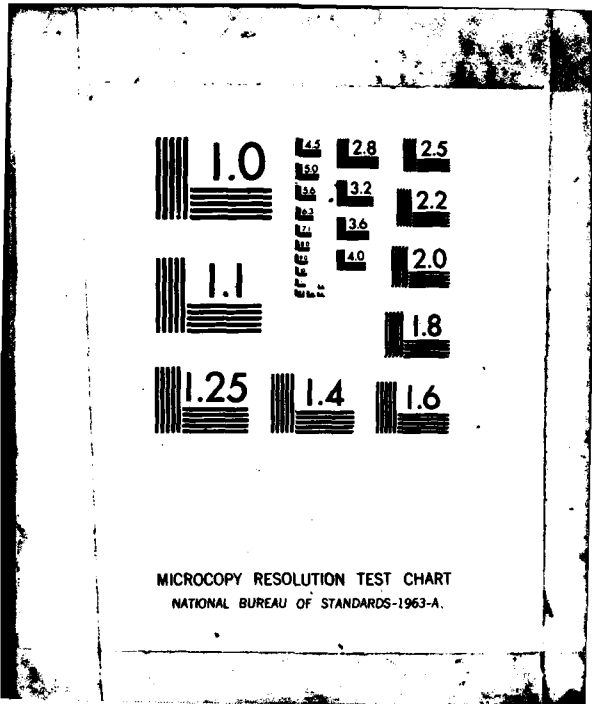
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THE AIRLINE PILOT'S VIEW OF FLIGHT DECK WORKLOAD:
A PRELIMINARY STUDY USING A QUESTIONNAIRE

by

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SUMMARY

↳ The term pilot workload is associated with much confusion and controversy despite the important role played by this parameter in the flight evaluation of new systems and techniques. Subjective ratings-- still the most common and probably the most reliable method for assessing workload in flight-- are made mainly by test pilots. But they must relate their experience to the pilot community as a whole, and so it is important that any definition of workload-- for the purpose of subjective assessment-- should reflect the opinion of pilots in general.

This study, using a self-administered questionnaire, was designed to find out what pilots think about workload both as a concept and also from the viewpoint of their own particular flying task. Answers to the questionnaire show that some 80% of pilots think of workload as being related to effort. It is also evident that a considerable diversity of opinion exists between pilots regarding workload levels associated with different aspects of their flying.

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LIST OF CONTENTS

	<u>Page</u>
1 INTRODUCTION	3
2 METHOD	3
3 RESULTS	3
4 DISCUSSION	7
5 CONCLUSIONS	10
Appendix A Introduction to pilot workload questionnaire	13
Appendix B	18
Appendix C	21
References	25
Report documentation page	inside back cover

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1 INTRODUCTION

A survey of the extensive literature on pilot workload underlines the confusion and controversy associated with the subject. However, despite the many different interpretations it is possible to divide them into two broad conceptual areas. The first considers workload in terms of the demands imposed by a particular task and the second views it as the response to those demands or as operator effort. It should be noted, though, that because measurement of performance alone is sometimes used to estimate workload some authors may consider this parameter to constitute a third conceptual area.

The assessment of pilot workload frequently plays an important part in the flight evaluation of new systems and techniques. For many years pilot workload studies at RAE Bedford have involved both subjective assessments by pilots and measurement of their heart rates. But one of the most difficult problems in this area is in agreeing on one definition equally acceptable to pilots, engineers and scientists. Subjective ratings - still the most common and probably most reliable assessment method - are made mainly by test pilots. They must relate their experience to the pilot community as a whole and so it is important that any definition - for the purpose of subjective assessment - should reflect the opinion of pilots in general as to the nature of workload.

It is pertinent, then, to ask which of the above conceptual interpretations of workload is the most appropriate for the pilot. This study attempts to answer the question by means of a questionnaire circulated to a number of air transport pilots, and, in addition, to identify individual components of overall workload and to determine pilots' attitudes to different levels.

Originally it was intended to construct a questionnaire suitable for circulation to both military and civil pilots; and because of the diverse nature of military flying many of the questions were open ended. It was appreciated that this would make analysis difficult, but it was thought that any consensus of opinion achieved in this way would be worth having. In the event, the questionnaire - in a considerably larger number than initially envisaged - was circulated to civil pilots some time before approval was obtained from the Royal Air Force. Although a substantial number of military pilots have now completed the questionnaire this Memorandum is concerned only with data from the civil pilot group. It is intended to publish the findings of the study involving RAF pilots at some future date.

2 METHOD

116 copies of a questionnaire consisting of 12 questions of varying complexities (Appendix A) were circulated to civil pilots flying a variety of passenger transport aircraft types belonging to three British independent airlines; and to communications pilots flying executive (third level) aircraft. A senior pilot in each organisation was asked to distribute the questionnaire to a representative cross section of captains and first officers (FOs).

3 RESULTS

98 fully, or almost fully, completed questionnaires were received from 51 airline captains, 41 airline FOs and six communications pilots. Of the 92 airline pilots, 33

captains and 22 FOs operated 'two-pilot' aircraft, and 18 captains and 19 FOs operated 'three-crew' aircraft. For the purpose of comparing answers from captains with those from FOs, based on experience levels four commercial pilots have been equated with captains and two with FOs.

Questions 1, 2 and 3 were intended to establish the qualifications and experience of the pilots taking part in this survey. Eight pilots had less than 1000 flying hours and eight had more than 10000 hours; the majority (66) had between 2000 and 10000 hours. Additional qualifications, experience and responsibilities are detailed in Appendix B, Table B1.

In question 4 pilots were asked to rank in order of workload the different phases of their overall flying task. Unfortunately, because the individual flight phases were not defined in the questionnaire it was sometimes difficult to separate them adequately in the answers. For instance, some pilots combined take-off and departure, or take-off and initial climb whereas others referred individually to take-off, departure and initial climb. Similarly, arrival and final approach and landing were not always separated. This confusion resulted in several scores of half-points in the results.

It was possible to identify nine phases of flight from the answers with take-off, departure, arrival and final approach and landing being most frequently mentioned as high workload phases. Several pilots referred to high workload tasks on the ground - mainly on the flight deck but also off the aeroplane. A minority of pilots specified changes to the flight plan outside the normal tasks such as diversions, re-routing and go-arounds as generating high workload. As the question referred only to flight phases it seems likely that some pilots would consider ground tasks and changes in flight plans to be inappropriate answers.

The four highest workload phases, the number of times each was rated, and a weighted rating are shown in Table 1. The weighting was obtained by scoring 4 points for a first ranking, 3 for a second and so on.

Table 1

Phase	Number of ratings	Weighted rating	Overall ranking
Arrival	80.5	252.5	1
Departure	66	170.5	2
Final approach and land	76.5	168	3
Take-off	72	159	4

In view of the open-ended nature of the question no great significance is claimed for the weighted ratings but they help in identifying high workload areas.

A more detailed table of rankings is presented in Appendix B, Table B2.

Question 5 was designed to show just how high pilots considered their workload to be in relation both to the overall flying task and to the highest workload phase. The results are given in Table 2. Some pilots divided their answers between two ratings and so once again half scores appear in the results.

Table 2

Rating	Overall task	Highest workload phase
(a) Too high	Nil	3½
(b) Very high but tolerable	9	64
(c) Moderate	77½	28½
(d) Low	9½	Nil

Of the 3½ scores for workload being too high during the highest workload phase 2 were from FOs of two-pilot aircraft, one was from a captain and half was from a FO of three-crew aircraft.

The way in which pilots viewed the relative importance of mental and physical workload was addressed by question 6. Table 3 presents the opinions of all 98 pilots for the overall task but - for some unknown reason - only 92 pilots gave opinions for the highest workload phase.

Table 3

	Overall task	Highest workload phase
(a) Physical	-	-
(b) More physical than mental	3½	7½
(c) More mental than physical	73½	66½
(d) Mental	21	18

Question 7 listed a number of factors and pilots were asked to rate their individual contribution to the workload both during the overall task and during the highest workload phase. A weighted rating - obtained by scoring 4 points for 'overwhelming or very large', 3 for 'large', and 2 for 'small' ('very small or not at all' was not scored) - has been used to help in determining the relative importance of the different factors. Table 4 presents the results in a simplified form using only the eight highest scoring factors; the complete results are detailed in Appendix B.

Table 4Relative contributions of individual factors to total workload

Factor	Overall task		Highest workload phase	
	Weighted rating	Ranking	Weighted rating	Ranking
(a) Use of primary controls	146	8	230.5	3
(d) Navigation/nav aids	191.5	3	241	1
(e) Checklists	155.5	7	208.5	6
(j) Radio communication	195.5	1	219.5	5
(m) Overall flight management	184	4	227	4
(n) Visual look out	166	6	197	7
(o) Monitoring other crew	194.5	2	234.5	2
(p) Fuel planning	168.5	5	132.5	11

The varying effects on the flight task due to the workload becoming too high were revealed in the answers to question 8:

45 pilots neglected or deferred the less important parts of the task.

28½ suggested that the task could be completed but could not be sustained.

12 completed the task at a lower standard.

10½ pilots reported failure to complete important parts of the task.

Of the 66 pilots who added comments a significant number referred to the adverse influence on workload of Air Traffic Control and several pilots stressed the importance of crew co-operation. A selection of comments is given in Appendix C.

Question 9 asked pilots to describe any techniques used by them to reduce their workload. Seven different techniques were referred to by significant number of pilots and these are listed in Table 5. In addition various other techniques were described by individual and small numbers of pilots. These ranged from using visual signals to communicate with other crew members so as to reduce 'chat' and using 'abbreviated readback' of instructions on RT to using the autopilot and taking 'mental short cuts'. Fifteen pilots did not report using any different techniques to reduce workload.

Table 5

Techniques of workload reduction

Technique	Number of times mentioned
Planning	29
Anticipation	23
Some check from memory	21
Increased familiarity with task	18
SOPs	14
Improved administration	13
Delegation or crew co-operation	10

Question 10 sought to identify those phases of flight when there is little to do in the cockpit. 91 pilots admitted that workload is low during the cruise (52) or during the cruise on long sectors (39). Of these, 11 pilots considered the workload at these times to be too low, *ie* they would prefer to work harder. Interestingly, 3½ reported that the cruise workload is high because it requires an effort to remain alert!

Comments were added by 53 pilots. Predictably, several pilots of short-haul aircraft pointed out that they were always occupied; on the other hand, an appreciable number of medium-haul and long-haul pilots admitted to a tendency for boredom and inattention to occur. The importance of the time of day was underlined by some pilots and - perhaps surprisingly - a few pilots appeared to welcome the opportunity to relax during low workload phases of flight. Individual comments of interest are quoted in Appendix C.

In question 11 pilots were asked to rate six definitions or concepts of workload taken from the literature as very good, good, poor or very poor. Table 6 shows the number of times each definition was rated together with a weighted overall rating obtained by scoring 2 for 'very good', 1 for 'good', -1 for 'poor' and -2 for 'very poor' ratings.

Table 6

Definition (reference)	Individual ratings				Weighted overall rating	Ranking
	Very good	Good	Poor	Very poor		
a (1)	22½	27½	21½	20½	+9.5	4
b (2)	21	50	20	5	+62	1
c (3)	14	53	22	5	+49	2
d (4)	29	29½	26½	7	+47	3
e (5)	10	36	37	9	+1	5
f (6)	3	13½	32	41½	-95.5	6

47 pilots wrote comments - some at great length. The majority were critical of the use of jargon and of incomprehensible sentences, several referred to Flight's Roger Bacon's 'Yuckspeak' and suggested that some of the definitions be added to the Yuckspeak library! A small number of pilots offered their own definitions and some of these - together with other representative comments - are presented in Appendix C.

The last question (number 12) was designed simply to determine whether pilots consider workload to be related to the way in which the individual responds to the flight task or whether it is determined solely by the task. Two pilots were unable to decide between the two, 16 pilots considered workload to be the same and 80 pilots stated that pilot 'A' had the higher workload.

A substantial majority of pilots in commenting on their decision referred in particular to such factors as spare capacity (36), effort (21), concentration (21) and ability (18). Several individual comments are quoted verbatim in Appendix C.

4 DISCUSSION

That 98 out of 116 distributed questionnaires (88%) were returned must reflect, to a large extent, the interest shown in cockpit workload by practising pilots; a point reinforced by the obvious care and thought displayed both in the answers and in the comments. The individual approach to participating pilots by senior colleagues must also have contributed to the high response rate. Factors such as these do tend to minimise the criticism often aimed at research based on questionnaires that the data may be biased by the likelihood of self-selected volunteers, with an axe to grind, to participate.

A striking feature of the results is the considerable diversity of opinion among the 98 pilots - a diversity which on more detailed analysis could not be related to

aircraft type or airline and only occasionally to experience and size of flight deck crew. Of particular interest are the differences revealed by question 4, although it should be noted that due to the lack of clearly defined flight phases there may have been some confusion. For example, there were obvious overlaps between arrival and final approach and landing, and between take-off and departure. Nevertheless, it is clear that if arrival is combined with landing and take-off with departure the former is considered to be, by far, the highest workload phase. (The respective combined weighted ratings being 423 and 327.) Interestingly, of the 53 pilots who rated arrival and landing as the highest workload phase 34 or 64% were captains. On the other hand, of the 26 pilots who rated take-off and departure as the highest workload phase 17 or 65% were FOs. (These percentages can be compared with the overall proportion, in the study, of 56% captains to 44% FOs.) These differences are not easy to explain although one possible reason for the former is the fact that in bad weather approaches and landings tend to be flown by captains rather than by first officers. Differences in age and experience between captains and first officers may influence attitudes to workload during both flight phases.

Although only flight phases were specified in the questions, workload on the ground was mentioned often enough to suggest that the pre-flight and turn-round tasks generate significant demands on the crew.

In the answers to question 5 no pilot considered his overall workload to be too high and only nine pilots thought it to be very high. These were distributed more or less equally between captains and FOs and between two-pilot crews and three-member crews. Although only 3½ answers rated workload as being too high during the highest workload phase it is somewhat disturbing that any pilot should find this to be so. Unfortunately the reasons for these opinions are not known, perhaps they are related to individual ability and spare capacity. Certainly, there does not appear to be any association with crew size or with age and experience.

Unexpectedly, a small number of pilots interpreted workload as being more physical than mental (3½ for the overall task and 7½ for the highest workload phase). The piloting task, except during abnormal flight and increased 'g' manoeuvres, requires little physical effort^{7,8}, and so it seems likely that the above interpretations are based more on physical movements than on physical exertion.

The answers to question 7 underline - again - the diverse nature of opinions held by pilots, this time on what factors contribute most to total workload. For example, although 11 pilots rated the use of primary controls as a 'large' contributing factor during the overall task 18½ answers rated it as 'very small or not at all'. And during the highest workload phase four pilots rated this factor as 'overwhelming or very large' whereas six pilots rated it as 'very small or not at all'.

One might expect differences in aircraft type or in operating procedures to account for these variations in pilots' ratings but detailed analysis of the results has produced little evidence to support this view. Even the 'fuel planning' was not rated significantly differently by pilots of aircraft having a flight engineer. However, comparison of weighted ratings for captains and first officers (see Appendix B, Table B4) shows

three interesting variations. Whereas there was little difference in the use of primary controls during the overall task there was a marked difference during the high workload phase with captains giving a much higher rating than FOs. This difference raises the question of whether younger pilots attach as much importance to controlling the aircraft as do their older colleagues. On the other hand, first officers rated radio communication and navigation contributions to the workload during the overall task appreciably higher than did captains. Predictably, captains rated 'overall management' higher than did first officers although the difference seems to be significant only for the high workload phase.

Question 8, which examined the effect of too high workload on pilots, showed that almost half the pilots - evenly divided between captains and FOs - neglected or deferred the less important parts of the task. But of the 30% of pilots reporting adequate completion of the task though not sustaining it 72% were captains.

The importance of planning and anticipation in reducing workload was highlighted by the number of mentions in the answers to question 9; although on reflection one might have expected these factors to have been mentioned by appreciably more than 52% of the pilots. It is worth noting that some 15% of pilots did not admit to using any techniques to reduce workload.

Although high cockpit workload has been identified as a contributory factor in many accidents to transport aircraft there is increasing evidence that too low workload may be a more important factor. Certainly, complacent attitudes and under-arousal are known to occur during periods of flight when the task should have generated relatively high levels of workload. Accident rates to passenger transport aircraft tend to increase with increase in stage length⁹ and it is tempting to suggest that too low workload in the cruise may on rare occasions lead to an element of under-arousal during the descent and final approach. Comments indicate that in general pilots are aware of the dangers of too low workload and many pilots take positive steps to maintain their arousal at a reasonable level.

By presenting six definitions of workload taken from the literature it was hoped to get some ideas of how pilots viewed the different interpretations. Unfortunately, as made obvious by the comments, too much use of jargon tended to confuse the issue. Even so, it was possible to judge the relative acceptability of the two main conceptual areas - task and effort - from the weighted scores. Definition 'b', which is based on effort, is clearly the favourite - perhaps understandably as this definition was written by a test pilot for the introduction to a handling qualities rating scale². This conceptual area also forms the basis for definition 'c' and if the two scores are combined they result in a substantial rating in favour of workload as effort.

The good support for 'd' is interesting, from comments it is obvious that the idea of spare capacity in relation to workload appeals to a number of pilots. In addition the individual nature of spare capacity is not incompatible with the concept of workload as effort.

Thinking in terms of spare capacity - how much more load he can accept without jeopardising his performance - is a convenient way for a pilot to subjectively estimate levels of workload. RAE test pilots - using a rating scale based on one designed for assessing handling qualities² - find it convenient to think along these lines when estimating workload in flight.

Definitions 'e' and 'f' introduce the important factor of 'available time' - a concept that is frequently used as a basis for predicting levels of workload for use in cockpit design.

One of the principal objectives of this study is to find out what professional pilots understand by the much used term cockpit workload. Arguably, therefore, the final question is the most important. The answers show quite clearly that a large majority of civil transport pilots think of workload in terms of effort. The individual nature of workload - related to natural ability, experience and training - is obviously important from the point of view of flight safety. How a particular pilot responds to the demands of the flight task is what matters in the long run. And so it is understandable that most pilots view the broad concept of workload in this way.

The results of question 12 confirm the preferences shown in the answers to question 11 but it is interesting to note that several pilots who preferred task orientated definitions decided that pilot 'A' has the higher workload. This change of opinion must in part reflect the confusing nature of some of the definitions thus confirming many of the comments made by participants.

5 CONCLUSIONS

98 civil transport pilots have reported their views on cockpit workload by means of a questionnaire. Answers to 12 questions together with associated comments have provided data that should prove to be of value to scientists and engineers concerned with optimizing levels of workload.

With hindsight it is obvious that the questionnaire should have avoided the use of open-ended questions. For instance, if in question 4 the phases of flight had been well defined analysis would have been easier and the results more reliable. In addition, ground phases, diversions and go-arounds should have been included. Nevertheless, despite these deficiencies, it is clear that some 80% of pilots view workload as effort - a figure that is supported by a preliminary analysis of 250 questionnaires received from military pilots.

Several pilots differentiated between objective and subjective workload in their comments on question 12. This difference is important - perhaps fundamental - in establishing a concept of workload that is appropriate for pilots subjectively assessing workload in flight. There is evidence that a pilot's awareness or perception of the difficulty of the task determines his response - or workload. The marked diversity of opinion between pilots' answers, particularly to questions 4 and 7, underlines further the individual nature of workload. Of course, it could be argued that in order to avoid confusion one should avoid the use of the term workload altogether and refer instead to

flight task demands, or pilot activities, or to response, or to effort, etc! However, if the term pilot workload is to be used a suitable definition might be: pilot workload is the integrated physical and mental effort generated by the perceived demands of a specified piloting task.

Appendix AINTRODUCTION TO PILOT WORKLOAD QUESTIONNAIRE

Over the past few years there has been much talk about workload. Pilots (and other aircrew members) get overloaded; designers and other experts tackle the problem, and claim that their solutions will reduce workload. The claims are in many cases hard to prove or disprove. There is therefore a need for an accepted means of measuring workload. To this end, scientists, engineers, psychologists and doctors have been devising and trying different ways of making objective measurements of workload. Unfortunately, there has not yet been agreement on a definition of workload, and so although much progress has been made, it is not certain that it has all been in the right direction.

Very little of this work has been done by pilots, and we at Bedford have now been tasked with investigating methods for pilots' subjective assessment and measurement of workload. Since there is no point in trying to measure something without knowing what it is, we need to get as accurate a picture as we can of what pilots understand by 'workload'. For this we need your help, and so we have devised this questionnaire, which is intended for circulation to as wide a cross-section of pilots (civil and military) as possible. The questionnaire is therefore designed purely for workload research, and the completed answers will be treated in confidence.

We are concerned only with short-term or immediate workloads (the workloads found in flight). The problems of long-term workloads (those found over the working day, week etc) are outside the scope of this inquiry.

Questions 1, 2 and 3 should give us an idea of your background and experience, and this could be very important if different classes of pilot have significantly different (or essentially similar) views. Pay particular attention to question 3. For instance, if you are an OCU instructor we do not want you to answer the questionnaire in the context of the instructor's role; we want you to answer it in the context of the eventual front-line role of your pupils.

The rest of the questions are intended to enable us to get a complete idea of your attitudes to workload, its components and its effects. Please answer the questions as fully and as accurately as you can. It is your personal opinion rather than that of your colleagues that we want. Do not worry if your answers appear to contradict one another or appear to be unduly repetitious. For instance, you may rate several parts of question 7 as '1' or all parts of question 11 as '3'. If you do not have enough space, or wish to make additional comments, please feel free to attach separate sheets or to continue on the back. If you cannot or do not wish to answer specific questions cross them out (but we hope you will not need to do this).

Finally, thank you very much for helping us with this survey, whose outcome should eventually benefit the whole flying community.

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WORKLOAD QUESTIONNAIRE

EXPERIENCE AND ROLE

1 Flying hours: Total
First pilot

2 Do you have any qualifications or responsibilities (current or recent), that might be relevant to the inquiry, for example: Test Pilot, Flying Instructor, OCU Instructor, Flight Commander, Airline Check Captain? If so, please specify it below:

3 What is your current (or principal recent) flying role. If you are an instructor or supervisor, specify the role for which you instruct or supervise and answer the rest of the questionnaire for that role. Please avoid loose terms like 'fighter pilot', but be as specific as you can (eg 'single-seat interceptor' or 'airline first officer') and state aircraft type.

4 Consider the individual phases of your flying task. By phases we mean whole parts of the flight like take-off, climb, landing, air-to-air refuelling or weapon attacks rather than specific tasks or sub-phases like guns tracking or fuel system management.

Write down your flight phases in order of workload, starting with the highest workload phase. If your list looks like being too long, leave out the lower workload phases:

- (a)
- (b)
- (c)
- (d)
- (e)
- (f)
- (g)
- (h)
- (j)
- (k)

Please answer questions 5, 6 and 7 both in relation to the overall flying task and to the highest workload phase (answer 4(a)).

5 (Tick the most appropriate answer.)

Is your workload

- (a) Too high?
- (b) Very high but tolerable?
- (c) Moderate?
- (d) Low?

Overall task	Highest work-load phase

6 (Tick the most appropriate answer.)

Is your workload:

- (a) Physical?
- (b) More physical than mental?
- (c) More mental than physical?
- (d) Mental?

Overall task	Highest work-load phase

7 How do you rate the contribution of the following factors to your workload? Give them a rating of 1 to 4 where:

- 1 = Overwhelming or very large.
- 2 = Large.
- 3 = Small.
- 4 = Very small or not at all.

- (a) Use of primary flying controls (eg stick, throttle).
- (b) Use of secondary controls (eg trimmers, flaps, mixture).
- (c) Autopilot handling.
- (d) Navigation/Nav aids.
- (e) Completion of checklists.
- (f) Writing of flight log.
- (g) Airframe systems management.
- (h) Weapon system management.
- (j) Radio communication.
- (k) Crew intercommunication.
- (l) Other audio loads.

Overall task	Highest work-load phase

- (m) Overall flight management/captaincy decisions.
- (n) Visual lookout.
- (o) Monitoring other crew members.
- (p) Fuel planning.

Overall task	Highest work-load phase

Others (please specify)

- (q)
- (r)
- (s)

8 What effect does workload have if it is too high? (Tick the one most appropriate)

- (a) The task is completed, but at a low standard.
- (b) Less important parts of the task are neglected or deferred.
- (c) Important parts of the task are not completed.
- (d) The task is adequately completed, but could not be sustained.

Comments:

9 Do you use techniques to reduce your workload, and if so what are they? (eg doing checklists from memory when they have been specified as 'challenge and response').

10 (a) Are there phases of your flying task when you have little to do? If so, what are they?

(b) Do you regard the workload in these phases as:
(Tick the one most appropriate)

- (1) Low?
- (2) Too low (you would prefer to work harder)?
- (3) High because you have to make an effort to remain sufficiently alert?

Comments:

11 Below are some definitions and concepts of workload. Please rate each one from 1 to 4, where:

- 1 = very good
- 2 = good
- 3 = poor
- 4 = very poor

- (a) "A summation of such processes as perception, evaluation, decision making and actions taken to accommodate those needs generated by influences originating within or without the aircraft".
- (b) "The integrated physical and mental effort required to perform a specified piloting task".
- (c) "The level of effort required to perform a given activity or complex of tasks".
- (d) A concept of workload based on the idea of spare capacity, namely the ability (or capacity) to accomplish additional (expected or unexpected) tasks.
- (e) "The extent to which an operator is occupied by a task". (This definition stems from the time-limited capability of the human operator.)
- (f) "The rate of the summation of required crew-equipment performance time to the time available within the constraint regulated by a given flight or mission".

Comments:

12 Two pilots are flying the same task in the same aeroplane, and are achieving the same standard. This is only just within the capability of pilot A, who finds it very difficult. Pilot B, a more able individual, does not find the task difficult and accomplishes it easily.

Is the workload the same for both pilots, or is it higher for pilot A? Please explain your answer.

Appendix BTable B1ADDITIONAL EXPERIENCE, QUALIFICATIONS AND RESPONSIBILITIES

(Question 2)

Type	Captains	FOs	Comms	Total
Nil	25	29	3	57
Supervisor	5	2	1	8
Examiner	16	2	2	20
Instructor	23	11	1	35
Test pilot	2	-	2	4

Table B2FLIGHT PHASES AND WORKLOAD RANKINGS

(Question 4)

Phase	a	b	c	d	e	f	g	h
On ground	13	3	4	4	9	9	4	1
Take-off	14	16	19½	16	6	½	-	-
Departure	12	27	16½	8½	2	-	-	-
Climb	-	1½	8	17	8	10	3	1
Cruise	-	-	-	2½	19½	16	16	1
Descent	-	4½	9½	10	18	9	2	-
Arrival	37½	25½	10½	5	2	-	-	-
Final approach/landing	15½	18	19	14	4½	5½	1	-
Go-around, diversion re-route	6	1	7	2	3	1	-	-

Table B3

CONTRIBUTION OF INDIVIDUAL FACTORS TO TOTAL WORKLOAD

(Question 7)

Factor	Overall task ratings					High workload phase ratings				
	1	2	3	4	Weighted	1	2	3	4	Weighted
(a) Primary controls		11	56½	18½	146	4	48½	34½	6	230.5
(b) Secondary controls		8	54	25	132		26½	58	8½	195.5
(c) Autopilot handling		12½	45	30½	127.5		10½	39½	43	110.5
(d) Navigation		33½	45½	7	191.5	7	55	24	7	241
(e) Check list	1	13½	55½	16	155.5	5½	33½	43	11	208.5
(f) Flight log		11	43½	34½	120	1	8	35	48	98
(g) Systems manager		7	44	34	109		9	47	33	121
(j) Radio comm.	½	39½	37½	8½	195.5	8½	48½	24	12	219.5
(k) Crew intercomm.	1	8	49	30	126	1½	21½	44	26	158.5
(l) Other audio loads	1	11½	33½	44	105.5	2½	19½	38	33	144.5
(m) Overall flt. man.	1	27	49½	8½	184	5	49	30	7	227
(n) Visual lookout		21	51½	14½	166	5	24	52½	10½	197
(o) Crew monitoring	1	28½	52½	8	194.5	2½	51½	35	4	234.5
(p) Fuel planning	1	10½	66½	10	168.5		12½	47½	33	132.5

NOTE: Weighted ratings were obtained by scoring:

- 1 'overwhelming or very large' × 4
- 2 'large' × 3, and
- 3 'small' × 2
- 4 'very small or not at all' was not scored.

Table B4CONTRIBUTION OF INDIVIDUAL FACTORS TO TOTAL WORKLOAD

(Weighted ratings for 55 captains and 43 First officers)

Factor	Captains		First officers	
	Overall task	Highest WL	Overall task	Highest WL
(a) Primary controls	66.5 (85)	*112 (143)	61	*87.5
(d) Navigation	*71 (91)	100.5 (128.5)	*100.5	112.5
(e) Check list	63.5 (81.5)	97.5 (125)	74	83.5
(j) Radio comm	*75 (96)	96 (123)	*99.5	96.5
(m) Overall flt. man.	85 (108.5)	*113.5 (145)	75.5	*82
(n) Visual lookout	69 (88)	86 (110)	78	87
(o) Crew monitoring	79 (101)	111 (142)	93.5	92.5
(p) Fuel planning	69 (88.5)	*69 (88.5)	80	*44

NOTE: 1 The scores for captains have been adjusted (original scores in parentheses) to allow for the difference in numbers.

2 For the purpose of comparison four commercial pilots have been equated with captains and two with FOs.

* Substantial difference between ratings.

Appendix C

A surprising aspect of this study has been the number of pilots who volunteered detailed and often lengthy comments, observations and suggestions. Some of these are presented in this Appendix.

Questions 8 and 9, which were concerned with too high workload, resulted in a large number of comments. Many were critical of the amount of paperwork required in flight and some pilots considered much of it could be reduced. For example:

"Flight log and other ancillary paperwork would be deferred on very short high workload flights."

"I do not do any paperwork on the climb or descent"

"... much of the paperwork seems to be of doubtful value and could probably be reduced without affecting operational standards."

Among the suggested techniques to reduce workload planning and anticipation were mentioned most often and the following comments are typical:

"Workload can be considerably reduced by good pre-planning and anticipation."

"The task should be planned ahead so that even if unexpected additions occur in the workload (as planned) they can be integrated into the task with no detriment to the task requirement at that moment. The plan should be constantly updated to cater for these additions."

Some pilots abbreviated checks or carried them out from memory during very high workload but other pilots preferred to follow SOPs rigorously.

"... checks from memory when necessary."

"... tend to use memory and abbreviated check lists."

"Some rearrangement of the task is usually possible to spread the workload."

"Experienced crews can reduce workload by their familiarity with check lists but inexperienced crews cannot cut corners and the workload remains high."

"SOPs are to me the techniques which have done most to reduce workload. These, together with reliable aircraft systems, good pre-flight planning, training and constant practise and reliable weather reports have made most aspects of my job routine."

"I try to operate to standard procedures regardless of weather or ATC situations. By doing so SOPs become second nature and one is able to cope with added or unexpected workloads more easily and mistakes are less likely. To go non standard under pressure is to live dangerously."

Comments about low workload during flight (question 10) included the following:

"Workload should be as low as possible, especially when plenty of time is available to complete the task."

"The unchanging engine note, lack of visual cues outside and lack of anything happening all combine to produce a semi-comatose state", - written by a pilot of a 'long-haul' aircraft referring to cruise at night over water. A few pilots on long haul reported occupying the time during the cruise with such activities as crossword puzzles in order to maintain an adequate level of mental activity.

" ... important to keep some mental activity going."

"I find sectors over 2 hours duration drag and I look for things to do."

"Workload is a factor of mental and physical activity to carry out a particular task. In the cruise phase this is low whilst monitoring the flight path and aircraft systems. Inability to remain alert is a factor of lack of physical and mental fitness not low workload."

One pilot suggested that "Transcendental meditation and 5-BX exercises improve ability to work and reduce fatigue."

And finally from a HS 748 captain:

"Boredom is a luxury we do not possess in a two-crew operation."

As one might expect questions 11 and 12 resulted in an abundance of comments several of which preferred alternative definitions or interpretations of workload. The general response to the six definitions of workload presented in question 11 was to request simpler wordings. The following comment was made by a pilot who rated 'b' as very good.

"A definition should be kept simple. Furthermore, its meaning should be grasped at one reading. If the definition is over complicated, the answers suggested to reduce workload will probably also be over complicated."

One pilot wrote:

"Unable to answer question - a more simplified choice of definitions required."

One pilot pointed out that modern jet transports do not require any great physical effort and he suggested that definition 'b' be amended to:

" ... integrated physical co-ordinations and mental effort"

A Boeing 727 captain wrote:

"Workload I think is best described as: the total demand caused by various (all) requirements to conduct the flight operation."

In answering question 12 this pilot rated 'As' workload to be higher than 'Bs'.

Other suggestions included the following:

" ... workload is the amount of mental and physical activity required at any given time relative to one's spare capacity."

" ... workload can only be applied to an actual activity and not to a hypothetical task"

" ... workload consists not so much of the number of things which have to be done, but of the pressure under which they are done"

"A pilot's workload is an amalgam of standard tasks coupled with the in-flight situation variants recurring on each flight at any given moment."

"Workload is the quantity of work required to be handled at a given moment and not the amount of effort required to achieve it."

In answer to the next question - as one would expect - this pilot rated both A and B as having the same workload. But he then commented on question 12 thus:

" ... the less experienced pilot might not be able to cope with additional problems because he would become overloaded."

The last comment on workload definitions was written by a Boeing 737 captain:

"The concept of workload as a parameter of relevance to aircrew efficiency is not really satisfied by definition (a) and it is the individual reaction to the various processes that is significant. (b) and (c) come much closer as they indicate the effort required for these. Effort is a quantity which is very difficult to measure other than subjectively. This subjective element is included in definitions (d) and (e). Definition (f) is good but suffers from the limitation that although the various tasks may fill the time available it may also be possible to perform extra tasks simultaneously."

Although only 20% of pilots considered 'A' and 'B' to have the same workload they included a number experienced training captains. But a highly experienced senior check captain wrote:

"Higher for pilot A. He is expending more energy (mental mainly), working harder. The *work* is the same, his *workload* is higher."

Other representative comments included:

"If a pilot has to produce more effort in order to achieve the same standard his workload must be higher."

"I feel that capacity and workload are related."

"The workload is the same for both pilots. However, pilot A applies more effort to achieve it and will sustain it for a shorter period than pilot B."

"The actual workload is the same but pilot A has to work harder to achieve the same as B."

"The workload is the same for both pilots. In any flight there is a finite amount of work. For an experienced pilot this work should be achieved without great effort and from this supposition it can be said that the experienced pilot could handle additional work in the form of emergencies, etc should they arise. However, the less experienced pilot might not be able to cope with additional problems because he would become overloaded."

The last three comments attempt to differentiate clearly between workload and effort. Several pilots differentiated between subjective and objective views of workload. For example:

"Objectively - workload is the same. Subjectively - and this is what I understand by workload - pilot A has a higher workload than pilot B."

Some pilots commented that pilot A may be more likely to develop an anxiety which would further reduce his ability. "Pilot A may be likely to have to work under more stress."

Other pilots pointed out that although pilot B has the lower workload he could become overconfident or complacent which could lead him into making mistakes.

REFERENCES

- | <u>No.</u> | <u>Author</u> | <u>Title, etc</u> |
|------------|---|--|
| 1 | C.R. Tennstedt | The pilot - his problems and requirements in: Symposium.
Flight deck environment and pilot workload.
Royal Aeronautical Society, London (1973) |
| 2 | G.E. Cooper
R.P. Harper | The use of pilot rating in the evaluation of aircraft handling
qualities.
NASA Technical Note 5153, Washington DC (1969) |
| 3 | L.L. Jenney
H.J. Older
B.J. Cameron | Measurement of operator workload in an information processing task.
NASA Contractor Report CR 2150, Washington DC (1972) |
| 4 | W.F. Clement
D.T. McRuer
R.H. Klein | Systematic manual control display design in Conference Proceedings
No.96. Guidance and control displays.
AGARD, Paris (1971) |
| 5 | D.W. Jahns | A concept of operator workload in manual vehicle operation.
Forschungsinstitut fur Anthropotechnik
Forschungsbericht Nr 14 Meckenheim (1973) |
| 6 | E.L. Brown
G. Stone
W.E. Pearce | Improved cockpits through flight crew workload measurement.
Paper presented to second advanced aircrew display symposium,
Naval Air Test Center, Patuxent River (1975) |
| 7 | D.E. Littell
R.J.T. Joy | Energy cost of piloting fixed and rotary wing aircraft.
J. App. Physiol. 26, 282-285 (1969) |
| 8 | A.S. Blix
S.B. Strome
H. Ursin | Additional heart rate - an indicator of psychological activation.
Aerospace Med. 45, 1219-1222 (1974) |
| 9 | Anon | Accident rates. US Air carriers. All type accidents, 1968-1977.
NTSB Safety Information Release, 17 October 1978 |

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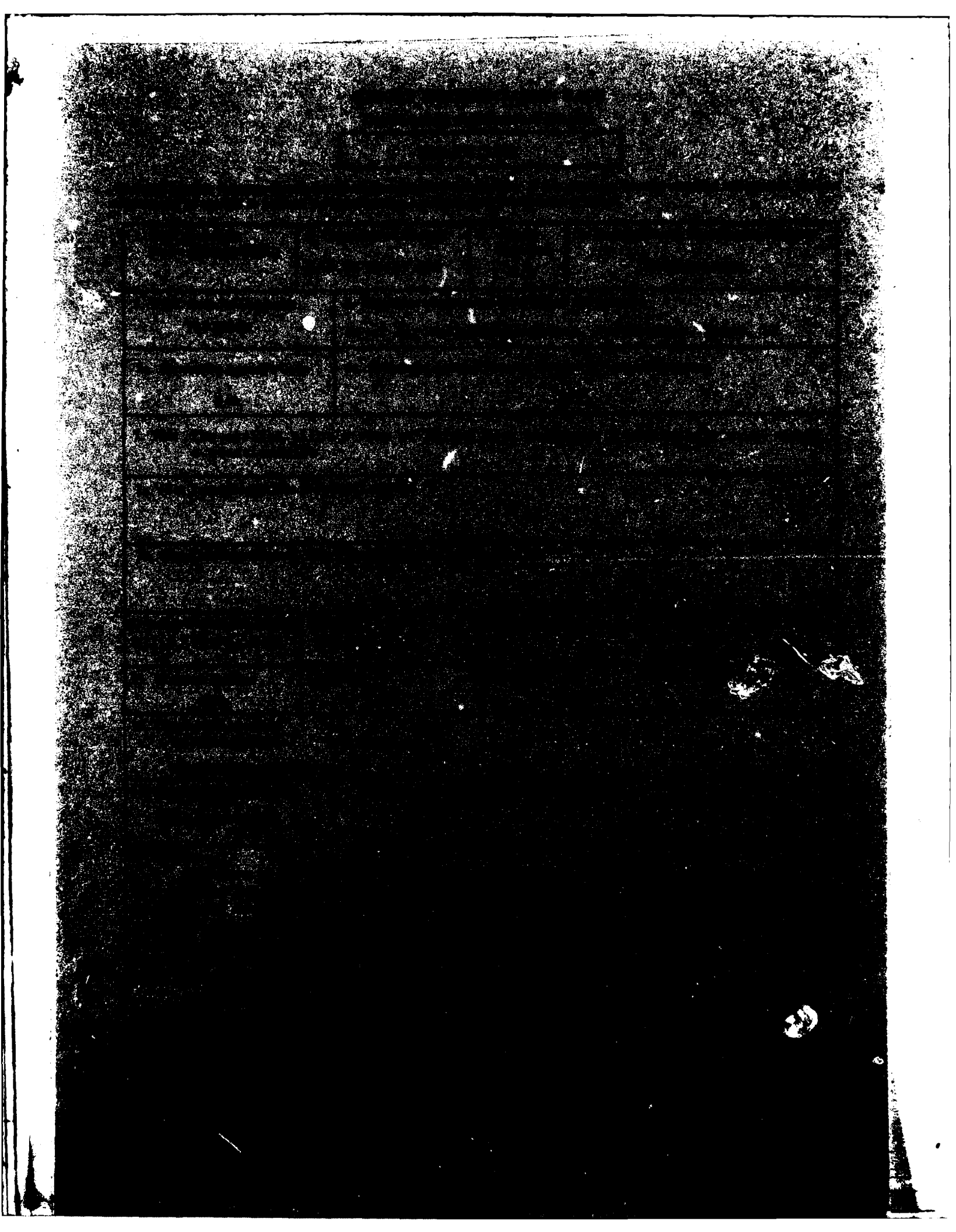
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