DESIGN OF WORK CONTROL CARDS

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1.0 ABSTRACT

The workcard is the prime source of on-line directive and feedforward information in aircraft inspection, and serves as a prime factor influencing inspection performance. The present study develops a methodology for design of workcards, based on the application of human factors knowledge to the analysis of aircraft inspection tasks. A taxonomy for design of usable documentation was developed, comprising four basic categories: Information Readability, Information Content, Information Organization, and Physical Handling and Environmental Factors. Within the framework of this taxonomy two extreme representative conditions of aircraft inspection tasks, the A-check and the C-check, were analyzed for the use and usability issues of the workcards. Issues were identified within the taxonomy using data from user responses. This data was then used to develop and propose alternate design solutions offering improved usability. Not only does this study propose specific design solutions, but it also provides us with a highly generic methodology that can be followed for design of quality documentation for other aircraft inspection tasks, and for design of usable information for automated jobcards, and hypermedia-based documentation.

2.0 INTRODUCTION

The work control card is the primary document that starts the inspection and serves as a prime influencing factor on inspection performance. If these costs are due to failure to detect a fault, or due to faulty detection, or are weighed against the cost of designing and providing quality documentation, considering the high risks involved, a strong case can be made for developing improved documentation. There is need for a definite methodology coupled with a set of guidelines for design of documentation. This study develops such a methodology based on the intersection of human factors knowledge with the analysis of aircraft inspection tasks. The methodology developed, being highly generic, can also be extended for design of information for portable computer based jobcards, as well as hypermedia based documentation for inspection and maintenance tasks.

3.0 GUIDELINES FOR DESIGN OF EFFECTIVE DOCUMENTATION

3.1 A TAXONOMY OF ISSUES IN DOCUMENTATION DESIGN

From the extensive Task Analysis of inspection generated in Phase 1 of this program (Shepherd, et al., 1991) and from the literature on the human factors of information presentation, evolved a taxonomy for design of usable documentation comprising of four basic categories, namely

1. Information Readability
2. Information Content
3. Information Organization
4. Physical Handling and Environmental Factors

3.2 INFORMATION READABILITY

Typographic Layout. "Typography without words", as it is referred to by some, is a means of addressing some conceptual issues that underpin typography, comprising the use of vertical spacing, lateral positioning, paragraphing and heading positioning, etc. All the principles of typography cannot be satisfied when the space available is premium, and use of secondary typographic and spatial cues becomes essential. Typographic cueing refers to use of variations in the appearance of the text in order to provide a visual distinction, e.g., boldfacing, italics, underlining, color coding, capital cueing etc. Also, advances in computer technology and word processing provide us with new tools such as right justification of typographic material, which improves reading speed considerably as compared to an irregular margin (Fabrizio, Kaplan, and Teal, 1967).

The Sentence, the Word and the Letter. Every printed language has some conventions, which the readers are familiar with, and disruption of reading results when these conventions are violated (Haber & Haber, 1981).This suggests that readers routinely use print arrangement as a source of visual information. In addition to the context, the shape alone of the entire word may prove to be useful in specifying its meaning. Carroll, Davies and Richman (1971), demonstrated this using very high frequency words from text (e.g., "the", "and", "it"). However, when the text is presented in all capitals, little or no word shape information is present, indicating a waste of an information resource. Since words are basically composed of letters, each of which has a distinct identity and name, a part of the visual information in reading must include the visual features of the individual letters of the alphabet, yet most fonts have additional redundant features like serifs which are irrelevant in visual processing (e.g., Times typeface).

3.3 INFORMATION CONTENT

A workcard writer must not blindly convert all the available relevant information into work control information, but rather anticipate the use that this information will be put to, in what context, and the good or bad influences that it will have on user strategies.

User Strategy Biases. The strategies that the end user adopts may be biased due to a number of reasons, and the information provided in the form of work control information may act as being one of them. One of the reasons may be due to poor cognitive monitoring on part of the user, i.e., they think they know the information and are thus biased towards using primitive routines in accomplishing the task. Also if the information provided is inappropriate and involves increased cognitive costs on part of the user, then the user selects strategies to reduce these cognitive costs by making use of sub-optimal strategies.

Appropriate Information Content. To reduce and eliminate user strategy biases and consequently improve the usability, the information should incorporate the following qualities:

- it should be accurate
- it should be complete, including information regarding: What is to be done, where, how, in what sequence, which specific items to pay attention to.
- up to date with revisions and updates
- easy to use and comprehend
- be written in a consistent and standardized style and syntax
- be clear and unambiguous
- be specific and contextual, e.g., pertaining to the particular aircraft being inspected
- flexible, i.e., to support both the expert as well as the novice user
- use only approved and proper acronyms
- have logical and uncontradictory statements

Graphic Information. Plain text can be uninviting to read and at other times involves high cognitive costs of interpretation. The same objective can be achieved at lower cognitive costs by use of graphic information provided that the graphic information is designed and presented in an appropriate manner. At times verbal information becomes difficult to comprehend, especially while conveying spatial information, hence graphics support provides an economical solution. An ideal content in graphic information should provide for a context for location and identification. Also items not relevant to the task should be eliminated to avoid clutter.

3.4 INFORMATION ORGANIZATION

Classification of Information. Information in any work control card can be clearly distinguished into: directive information, references to additional information, warnings, cautions, notes, and procedures and methods for achieving certain goals. They should follow a standard prioritized order within the document itself, e.g. warning should precede cautions and notes. Inaba (1991) suggests that directive information should not include more than two or three related actions per step, keeping in mind the limitations of the human short term memory. All directive information can be broken into three distinct subgroups: the command verb; the objects and the action qualifier. The command verbs must be selected from a list of verbs which has no synonyms, to reduce the level of ambiguity. The objects need to be broken down into further subgroups to account for action slips. The action qualifier should be distinct from the other two, and may begin with a standard article like "for". An example of the four sub-groups differentiated by typeface is:

Check: - all hydraulic lines

- control cables

- pulleys

for wear, frays, damage, and corrosion

3.5 INFORMATION LAYERING

A novice inspector may require elaborate information at every stage; an expert on the other hand might require brief information. The information organization should be such that it caters to the needs of both, the prime goal being to make it more flexible and more context sensitive (Jewette, 1981). Multiple levels can be built into the information organization, for example, having the main ideas at the first level, followed by elaboration of each of the main ideas at the second level, and finally detailed descriptions at the lowest level. A number of methods can be adopted to present multi-layered information in hard copy format: using distinctly separate layers (for example, a checklist and a detailed information sheet); indented paragraphing (Jewette, 1981); use of color, graphical anchors, boxes; use of different print sizes and styles; use of symbolic nomenclatures e.g., "A", "B", "1.1", etc. Also, at the lowest level, other tools such as italics, boldface, underlining, brackets, footnotes, appendices etc. can be used.

In addition to the obvious advantages to the user in terms of flexibility of usage, multi level writing has some distinct advantages to the writer. It is easy to write, as it has a preset framework within which to write. It is less dependent on fancy phraseology. Sequencing and rearranging of information becomes an easier task, with less planning requirements. The amount of redundancy in the information is also considerably lower. It involves the use of explicit statements of intention and is hence less error prone.

Other Organizational Issues. Ideally speaking, both text and graphics should be presented on the same page or facing pages, but for reasons of cost effectiveness and system limitations this may not be feasible at all times. The page size should be treated as a naturally occurring module within a document, in the physical sense. The information should be organized according to a rational task order, which may either be the most rational way of doing that task or may be the order followed by most inspectors, due to practical reasons discovered during workcard usage.

3.6 PHYSICAL HANDLING/ENVIRONMENTAL FACTORS

An ideal workcard can satisfy all the aforementioned principles of information design, but if it is not physically compatible with the task at hand, it will be of little use as people will be reluctant to use it.

Non-compatibility with the working environment can encompass a number of factors:

- physical handling difficulty due to unwieldy size
- excessively heavy, cannot be held continuously
- environmental degradation due to wind, rain and snow
- incompatible with the other tools used in the workplace e.g., lighting equipment, hand tools, etc.
- improper lighting conditions, need for a localized reading light

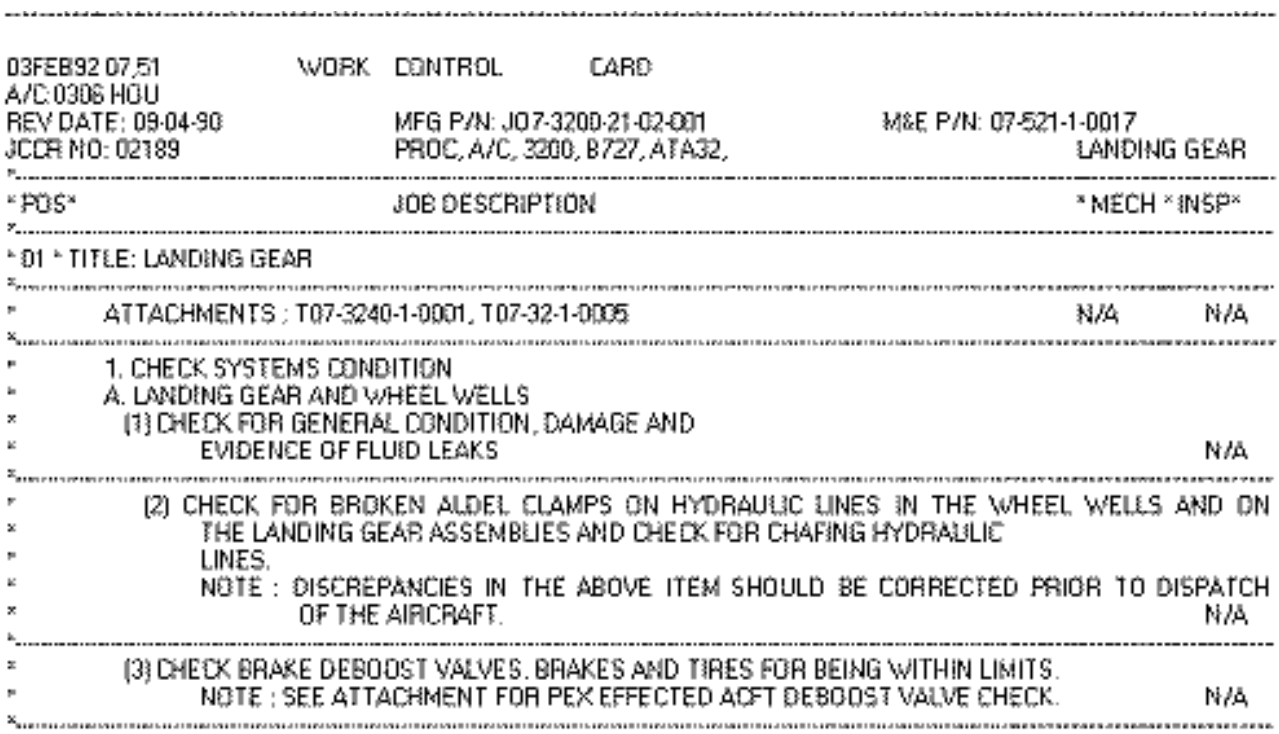
This issue is often neglected, and remains a problem in most "work area" usage of documentation. Handling and usage is a critical factor and will remain so even with automated job-cards using scratch pads or laptop computers. Providing a simple workcard holder can at times solve this problem. Depending on the task, however, a specialized design of a workcard holder may be essential to improve the usability of the documentation.

4.0 CASE STUDIES IN WORKCARD DESIGN

Within an aircraft schedule, inspection checks are performed at periodic intervals, ranging from routine flight line checks and overnight checks, through to A-, B- and C-checks, to the heaviest or the D-check. Among these, two extreme representative conditions were considered as demonstration case studies. The A-check is a more frequent but cursory inspection, while the C-check is a less frequent but more detailed inspection. Only the A-check case study is presented here for reasons of space.

4.1 A-CHECK CASE STUDY

Task Description. The maintenance supervisor assigns the A-check work control card to the technician. Normally two technicians are assigned to an aircraft, one technician is assigned with an assistant who helps in cleaning and aiding maintenance work. The two technicians proceed to the scheduled aircraft and begin the inspection which is usually carried out in the open, under all environmental conditions and with poor lighting. Any discrepancies or faults are noted on a non-routine worksheet. Normally, the maintenance technician completes the inspection and testing tasks before beginning work on reported discrepancies. The technician has to perform and sign off each of the 201 items mentioned in the workcard, in the scheduled time. A sample page from the current workcard is shown in **Figure 1**.



03FEB92 07.51 WORK CONTROL CARD
A/C 0306 HOU
REV DATE: 09-04-90 MFG P/N: JO7-3200-21-02-001 M&E P/N: 07-521-1-0017
JCCR NO: 02189 PROC, A/C, 3200, B727, ATA32, LANDING GEAR

* POS *	JOB DESCRIPTION	* MECH *	INSP *
* 01 *	TITLE: LANDING GEAR		
*	ATTACHMENTS : T07-3240-1-0001, T07-32-1-0005	N/A	N/A
*	1. CHECK SYSTEMS CONDITION A. LANDING GEAR AND WHEEL WELLS (1) CHECK FOR GENERAL CONDITION, DAMAGE AND EVIDENCE OF FLUID LEAKS		N/A
*	(2) CHECK FOR BROKEN ALDEL CLAMPS ON HYDRAULIC LINES IN THE WHEEL WELLS AND ON THE LANDING GEAR ASSEMBLIES AND CHECK FOR CHAFING HYDRAULIC LINES. NOTE : DISCREPANCIES IN THE ABOVE ITEM SHOULD BE CORRECTED PRIOR TO DISPATCH OF THE AIRCRAFT.		N/A
*	(3) CHECK BRAKE DEBOOST VALVES, BRAKES AND TIRES FOR BEING WITHIN LIMITS. NOTE : SEE ATTACHMENT FOR PEX EFFECTED ACFT DEBOOST VALVE CHECK.		N/A

Figure 1 Sample Page from the Current Workcard

The maintenance technicians who perform the A-checks range in age from 23 to 55 years, with an experience on A-checks varying between 1 year to 25 years. All the 201 signoffs within the A-check can be classified into 18 subtasks, which again can be collected into two general categories of tasks, namely "inspection tasks" and "testing tasks". The inspection tasks are those of visual inspection, to ascertain conformance to predetermined standards. Testing on the other hand involves determination of the proper functioning. Both inspection and testing can be further classified into "internal" and "external" tasks, depending on whether the task is to be performed on the interior or exterior of the aircraft.

Methods. Field visits were conducted to the various A-check inspection sites. These visits included direct observations of the task, observational interviews, and personal interviewing of experienced as well as inexperienced inspectors, technicians, and supervisors. In addition, a questionnaire study was conducted to obtain a broad range of user responses regarding workcard usability, from all A-check inspection sites within the airline. The questionnaire asked for information regarding the age and experience of the technician, coupled with a set of 12 scaled questions using a rating scale from 0 to 8; a set of five written feedback questions, and a final question asking for the sequence in which the user performed the 18 subtasks of the A-check.

Results. The taxonomy for documentation design was used to identify the issues relating to the current workcard design for the A-check as presented in **Table 1**. This study demonstrates how such a taxonomy can be used to analyze any existing documentation and to identify the key issues that need improvement.

Table 1 A-Check Workcard: Issues Identified Within the Taxonomy

1. INFORMATION READABILITY	
A. Typographic Layout	- no consistent typographic layout as such - layout discontinuous, breaks within pages - no usage of secondary typographic cueing, eg boldface, etc. - no use of right justification of typographic material
B. Sentence, word, and, (2.2.2)	- non-conformability with a few of the printing conventions listed in Table 1. - use of all capitals format, resulting in a low reading speed - no room for selecting an appropriate typeface - use of a 5x7 dot matrix typeface
2. INFORMATION CONTENT	
A. Appropriate content	- some level of inaccuracy in the information - incomplete information for certain tasks - language, difficult to use and comprehend - syntax not standardized - directive information ambiguous - generalization across aircraft types, is a cause of confusion - not flexible to use - use of difficult acronyms - logical errors and contradictory statements - redundancy and repetition - not consistent with user training - does not foster generalizations across tasks, as every task is described differently
B. Graphic Information	- system unsupportive of graphics - spatial information conveyed through text, results in the use of complex and lengthy sentences which are difficult to comprehend
3. INFORMATION ORGANIZATION	
A. Information Classific (2.4.3)	- no categorization or classification of tasks - notes, cautions, methods, directions, etc. not in any prioritized order - no demarkation between directive information, references, notes, methods etc. - directive information isn't broken up into command verb, objects, and action qualifiers - directive information includes more than two or three related actions per step - both, general as well as specific information chunked together - external as well as internal tasks not properly demarcated, mixed
B. Information Layering	- no layering of information - not conducive to expert as well as novice usage - difficulty in writing such unstructured information
C. Other organizations (2.4.3)	- no use of naturally occurring page modules for filling in information - improper sequencing of tasks
4. PHYSICAL HANDLING & ENVIR.	
	- physical handling difficult due to unwieldy size - excessively heavy, cannot be held continuously - usage in extreme environments difficult - not compatible with the other tools used along with, during the task

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	- physical handling difficult due to unwieldy size - excessively heavy, cannot be held continuously - usage in extreme environments difficult - not compatible with the other tools used along with, during the task - inadequate lighting conditions - no holder or place for holding the workcard while usage - all these factors force them to carry out the external inspection without the workcard, relying only on memory

A total of 60 questionnaire responses were received from fourteen sites. Most respondents had been in the industry for less than 15 years, had less than 14 years experience of maintenance, with less than 10 of it on A-checks. What emerges from the responses, is a moderate level of satisfaction with the current workcard, but a number of users who need different information. There was a substantial agreement that the current ordering of information was incorrect and that the sign-off procedure was not performed after every step. Table 2 summarizes the conclusions from the A-check rating scale questions. In addition, the questionnaire solicited open ended responses to questions. Over 200 such responses were obtained, showing that the technicians both had strong views and that they were willing to report them when given a formal opportunity. An analysis of the task sequence preferences obtained from the questionnaire responses was undertaken. Based on these responses, an optimal task sequence was developed, which again is in agreement with the four basic task divisions of the A-check pointed out.

Table 2 A-Check Questionnaire: Interpretations of Scaled Question

Responses

Q.No.	Interpretation
1.	- 66% of the users find the present workcard as a useful source of information
2.	- 60% of the users refer to the workcard while doing the A-check, either usually or always
3.	- most people feel that the readability of the current workcard is either fair or good
4.	- there is no unanimous opinion amongst the users, as to whether they prefer a concise or detailed workcard
5.	- almost half the users prefer a smaller size workcard, while the other half feel that the current size is about right
6.	- most users feel that the information provided on the workcard is only sometimes sufficient to carry out the A- check task
7.	- almost 50% of the users feel that the current workcard is moderately easy to understand
8.	- most users face problems either sometimes or always in physically using the workcard while working
9.	- 65% of the users do not carry out the A-check activities in the same way as listed out in the workcard
10.	- 80% of the users say that they have felt the need for more information that was not provided on the workcard, either sometimes or always
11.	- there is no unanimous opinion amongst the users, as to whether they use the A-check ACCT list provided at the beginning of the current workcard
12.	- 50% of the users signoff the completed tasks on the workcard at the end of the entire inspection

Work control card for A-check: Proposed design. Based on the issues identified in **Table 1** and the taxonomy, a design for the work control card for A-check's, has been proposed. This design comprises two parts: the design of the information and the paperwork itself and the design of a workcard holder.

The proposed workcard for the A-check has a two level hierarchical layering of information, as discussed. The top level is in the form of a checklist (Figure 2a), with brief task descriptions for each of the 201 signoffs, a place for the signoff itself and comments. This is the only part that is issued fresh to the inspector before an A-check. At the lower level is the detailed information in the form of a bound copy (**Figure 2b**), which remains the same until a new revision or update comes up. The directive information is broken up into the command verb, the objects, and the action qualifier as illustrated.

S.#	Description	P#	Signoff	Comment
A	**Landing gear and wheel wells**	---	------	--------
1.	General condition, damage, fluid leaks	5		
2.	Wheel wells, landing gear assemblies, hydraulic lines	5		
3.	Brake deboost valve limits	5		
4.	Brake limits	6		
5.	Tires, for wear, damage, fluid leaks	6		
6.	Nose wheel cap attached bolts	6		
7.	Nuts for bottoming of last tread	7		
8.	Shock struts for, normal extension, general condition, leaks	7		
B	**Tire pressure check**	---	-----	---------
1.	Tire pressure	7		
C	**Main gear doors**	---	------	---------
1.	Doors, operating cable, cranks & arms, general condition	8		
D	**Main gear wheel well down lock viewing windows**	---	------	---------
1.	Indicator stripes for clarity and legibility	8		
E	**Right and left main landing gear wing doors**	---	------	---------
1.	Presence and legibility of wheel chock location placard	8		

Figure 2a Proposed Design for A-Check Workcard: Checklist

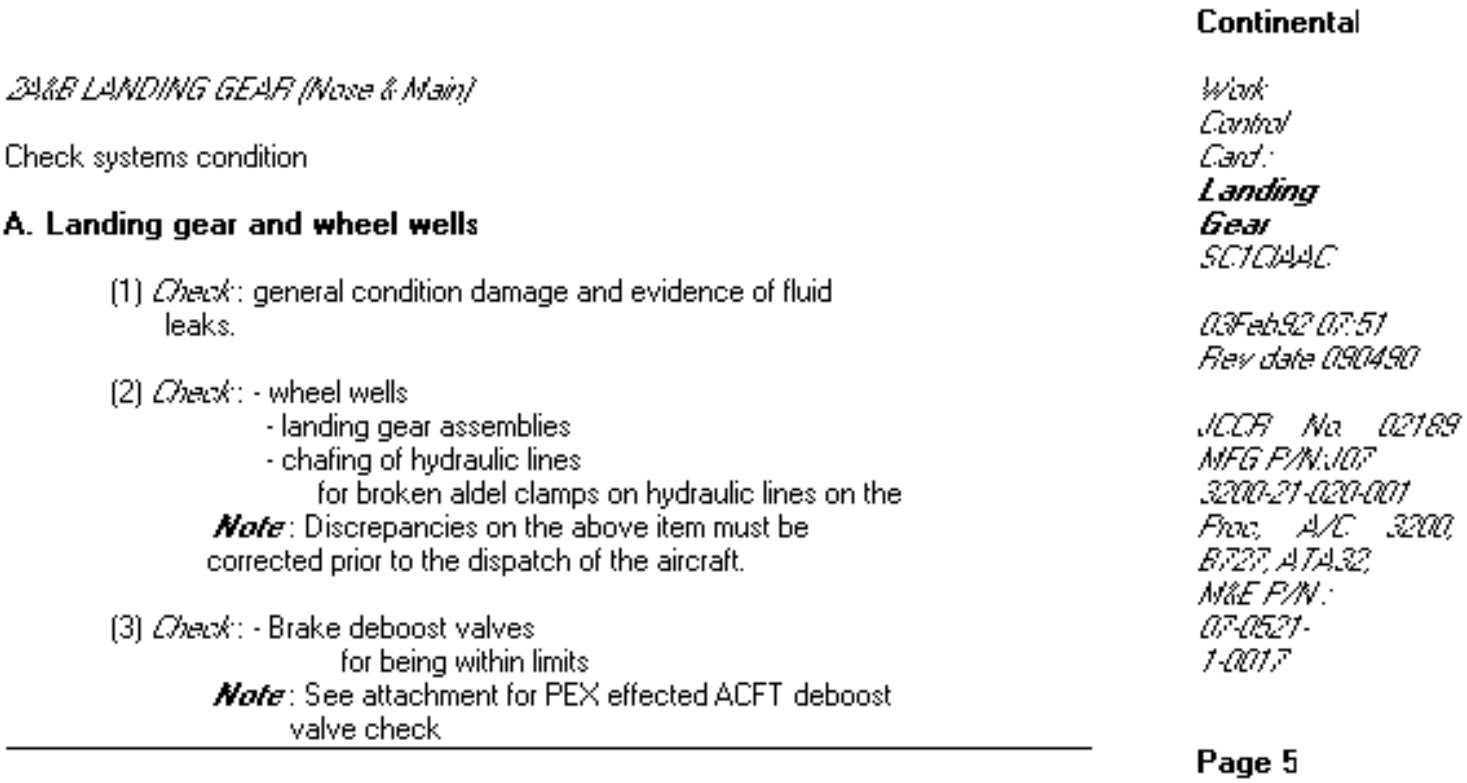

Figure 2b Proposed Design for A-Check Workcard: Detailed Information

A design was proposed for the workcard holder using the issues brought out in Table 1 under the heading of "Physical Handling/Environmental Factors." The top layer holds the checklist portion (19 pages) which can be clipped on every time before going out for an inspection, and the inner compartment holds the detailed information sheets, which remain in there until a new revision comes up. The top layer opens on a hinge which houses a small reading light to enable reading in poor lighting conditions. The holder also has paper retainer clips which aid usage in windy conditions. The prototype is shown in Figure 3.

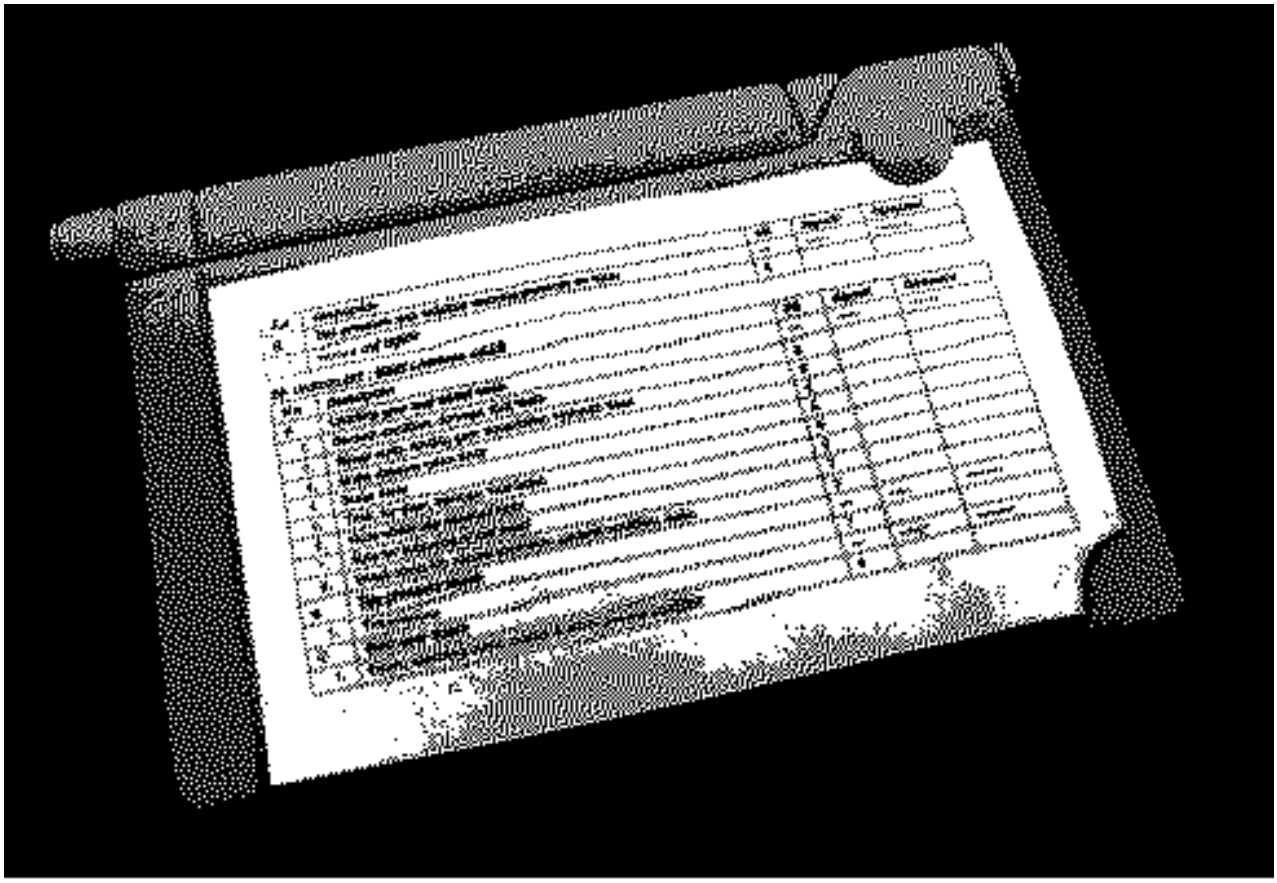

Figure 3 Prototype of a Workcard Holder

5.0 RECOMMENDATIONS AND CONCLUSIONS

The A-check case study, and the C-check case study not reported here, both showed that substantial redesign of the existing workcards is required. This is true whether they are to be replaced by new hardcopy workcards, or by a portable computer system. The taxonomy of documentation design presented here provides the framework required for investigating documentation in field conditions, using direct observation and user feedback in a structured manner to develop improved designs.

6.0 REFERENCES

Carrol, J. B., Davies, P. and Richman, B. (1971). *The American Heritage Word Frequency Book.* Boston: Houghton-Miftlin.

Drury, C. G. (1989). Information Environment in aircraft inspection. In *Proceedings of the Second International Conference on Human Factors in Aging Aircraft,*. Biotechnology, Inc., Falls Church, Virginia.

Fabrizio, R., Kaplan, I. and Teal, G. (1967). Readability as a function of the straightness of right hand margins. *Journal of Typographic Research, 1*, 90-95.

Haber, R. N. and Haber, L. R. (1981). Visual components of the reading process. *Visible Language XV, 2*, 147-182.

Inaba, K. (1991). *Converting Technical Publications into Maintenance Performance Aids,* XYZYX Information Corporation.

Jewette, D. L. (1981). Multi-level writing in theory and practice. *Visible Language, XV, 1*, 32-40.

Prabhu, P., Gramopadhye, A. and Drury, C. G. (1991). Human factors in workcard design: an initial presentation of the issues. Unpublished technical report prepared for Galaxy Scientific Corporation/FAA/ OAM.

Shepherd, W.T., Johnson, W.B., Drury, C.G., Taylor, J.C. & Berninger, D. (1991). *Human Factors in Aviation Maintenance Phase 1: Progress Report* (DOT/FAA/AM-91/16). Washington, DC: U.S. Department of Transportation, Federal Aviation Administration.

Wright, P. (1991). Quality: an excellent idea? In *Conference on Quality in Documentation,* Centre for Professional Writing, U.K., 11-24.