NAVAL POSTGRADUATE SCHOOL

Monterey, California

AD-A247 153

DTIC
ELECTE
MAR 09 1992
S B D

THESIS

CORRELATIONAL ANALYSIS OF SURVEY AND MODEL-GENERATED WORKLOAD VALUES

by

James J. Galvin Jr.

September, 1991

Thesis Advisor: Judith H. Lind

Approved for public release; distribution is unlimited

92-05869

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY 2b DECLASSIFICATION/DOWNGRADING SCHEDULE	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b OFFICE SYMBOL (If applicable) OR	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000	7b ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000
8a NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS Program Element No / Project No / Task No / Work Unit Accession Number

11 TITLE (Include Security Classification)
CORRELATIONAL ANALYSIS OF SURVEY AND MODEL-GENERATED WORKLOAD VALUES (UNCLASSIFIED)

12 PERSONAL AUTHOR(S) Galvin, James, J., Jr

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (year, month, day)	15 PAGE COUNT
Master's Thesis	From To	1991, Sept	99

16 SUPPLEMENTARY NOTATION
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 COSATI CODES			18 SUBJECT TERMS (continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUBGROUP	WORKLOAD, TASK LOADING MODEL, HELICOPTER PILOT WORKLOAD, ARMY AIRCREW/AIRCRAFT INTEGRATION PROGRAM, MIDAS, WORKLOAD SURVEY

19 ABSTRACT (continue on reverse if necessary and identify by block number)

This study examines the accuracy of an Army helicopter pilot workload measuring model called the Task Loading Model. The model is a submodel of the Army-NASA Aircrew/Aircraft Integration Program's Man-Machine Integration Design and Analysis System. The model's workload level output was correlated with the subjective workload measurements of several groups of pilots evaluating a variety of flight tasks. Seventy-one Army aviators completed surveys requiring scaled ratings and paired comparisons of workload related to common flight tasks conducted during typical missions. Their responses were examined for internal consistency and pooling by means of nonparametric tests. Aviator-supplied data was found to be robust and reliable. Pooled response data was correlated with model-generated data to determine the accuracy of the model. Results of this study show that the Task Loading Model is presently inadequate, but displays promising trends and should be further refined.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS REPORT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a NAME OF RESPONSIBLE INDIVIDUAL Judith H. Lind	22b TELEPHONE (Include Area code) 408-646-2543	22c OFFICE SYMBOL Code OR/Li

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

Approved for public release; distribution is unlimited.

Correlational Analysis of Survey and
Model-Generated Workload Values

by

James J. Galvin Jr.
Captain, United States Army
B.S., United States Military Academy

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1991

Author: ______________________________
James J. Galvin Jr.

Approved by: ______________________________
Judith H. Lind, Thesis Advisor

____
CDR Thomas M. Mitchell, Second Reader

____
Peter Purdue, Chairman
Department of Operations Research

ABSTRACT

This study examines the accuracy of an Army helicopter pilot workload measuring model called the Task Loading Model. The model is a submodel of the Army-NASA Aircrew/Aircraft Integration Program's Man-Machine Integration Design and Analysis System. The model's workload level output was correlated with the subjective workload measurements of several groups of pilots evaluating a variety of flight tasks. Seventy-one Army aviators completed surveys requiring scaled ratings and paired comparisons of workload related to common flight tasks conducted during typical missions. Their responses were examined for internal consistency and pooling by means of nonparametric tests. Aviator-supplied data was found to be robust and reliable. Pooled response data was correlated with model-generated data to determine the accuracy of the model. Results of this study show that the Task Loading Model is presently inadequate, but displays promising trends and should be further refined.

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification
Distribution/
Availability Codes
Avail and/or
Dist Special
A-1

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

A^3I	Army-NASA Aircrew/Aircraft Integration Program
AH-AB	Attack Helicopter Pilots of the Attack Helicopter Battalion
AH-CV	Attack Helicopter Pilots of the Cavalry Squadron
EO-AB	Enlisted Aerial Observers of the Attack Helicopter Battalion
EO-CV	Enlisted Aerial Observers of the Cavalry Squadron
ICS	Inter Communication System
MIDAS	Man-Machine Integration Design and Analysis System
NOE	Nap of the Earth
NASA	National Aeronautics and Space Administration
PSI	Pilot Steering Indicator
SH-AB	Scout Helicopter Pilots of the Attack Helicopter Battalion
SH-CV	Scout Helicopter Pilots of the Cavalry Squadron
TLM	Task Loading Model
TLX	Task Load Index
TSU	Telescopic Sight Unit

I. INTRODUCTION

A. BACKGROUND

1. Operator Error and the Design Process

Operator error is the primary cause of many aircraft mishaps. "Even if some divine power could guarantee that all mechanical and electrical systems used in aviation were 100% reliable, there would still be accidents due to human error" (Kantowitz, 1988, p.158). This is especially true in the demanding environments associated with military aviation. As technological advances raise the performance levels of modern military aircraft, the mission employment expectations placed upon the aircraft and their operators also rise. As a result, pilots encounter more difficult operational environments, experience higher workload demands, and frequently surpass their human performance capabilities.

There is a concerted effort among design engineers to reduce operator workload through cockpit automation. However, a large gap exists between the desired effects of automation and its actual ramifications. Instead of lowered operator workload, many well intentioned designs result in prolonged training, illogical tasking, and excessive demands on pilot adaptability. (Army-NASA, 1990, p.2)

2. Army-NASA Design Tool: MIDAS

The U.S. Army and the National Aeronautics and Space Administration (NASA) are working together to create a human performance model that overcomes the problem of good intentions and poor results. The Army-NASA Aircrew/Aircraft Integration Program (A^3I) is developing a computer simulation of aircraft crewstations and their operators. The simulation is to serve as a tool that can help ensure that human factors considerations are included in system design.

The Man-Machine Integration Design and Analysis System (MIDAS) is one part of the A^3I program's efforts. The MIDAS workstation presently simulates an AH-64 Apache helicopter, its pilot, and the environment in which they operate. MIDAS includes a variety of simulation submodels in areas such as anthropometry, vision, cockpit display layout, the pilot's cognition, and task loading. The synchronization of the MIDAS submodels results in a very capable design tool. (Army-NASA, 1990)

MIDAS developers envision an interactive computational system such as that illustrated in Figure 1. Use of such a system will improve the current design process in several ways:

1. It enhances the engineer's efficiency and creativity. He or she can configure a cockpit, test it with a human model, and immediately evaluate the design's suitability in a variety of environments.

2. Human factors considerations, often ignored during the initial phases of design, are a significant aspect of the feedback produced by MIDAS.

3. Extensive use of computer modeling will reduce the expensive development of faulty prototypes, thus reducing the research and development costs associated with a procurement program.

4. Although now configured as an Apache helicopter, MIDAS will be applicable to any man-machine vehicular system. (Army-NASA, 1990, pp.1-6)

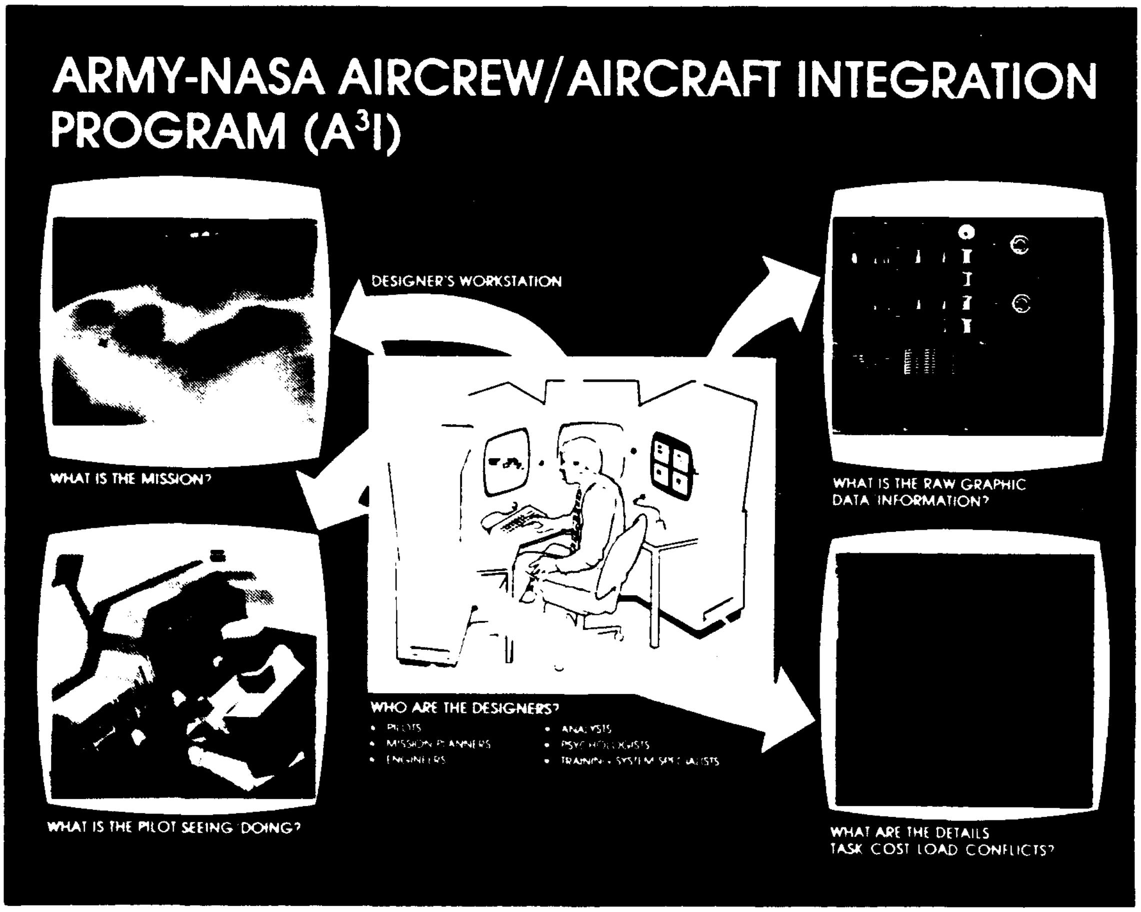

Figure 1. MIDAS Workstation Concept (Army-NASA, 1990, p.8)

3. MIDAS Task Loading Model

The measurement of pilot workload is an important aspect of the aircraft design process. "When workload is excessive, errors arise from the inability of the human to cope with high information rates imposed by the environment. When workload is too low, the human is bored and may not attend properly to the task at hand, also leading to error" (Kantowitz, 1988, p.159).

The Task Loading Model (TLM) is one high resolution facet of MIDAS. The TLM manipulates state variables related to the operator and the aircraft to calculate the operator's relative workload. The TLM output classifies the pilot's individual flight tasks and task demands across the visual, auditory, cognitive, and motor dimensions. The classifications and calculations generate workload data that designers may use to determine the level of human performance required for a specific system configuration. (Staveland, 1990)

Four dimensions of human performance are measured by the TLM. These four dimensions represent the visual, auditory, cognitive and motor activities of a pilot. The TLM subdivides the four dimensions into several elements, including near and far for a visual activity, salient and masked for an auditory activity, planned and unplanned for a cognitive activity, and gross and fine for a motor activity. Each task is classified according to the four dimensions and the elements within the dimensions. The TLM then generates workload values along each dimension. (Staveland, 1990)

B. TLM PROBLEMS

Several problems and uncertainties currently are associated with the TLM. First, the nature of human workload is not fully understood. Although the model incorporates "current research in multiple resource theory, scaling, workload, and perception" (Army-NASA, 1990, p.14), limitations in the field of behavioral psychology still limit the model. Second, current workload measurement mechanisms cannot capture all aspects of task loading and human performance. Thus, behavioral scientists skeptically view attempts to compile workload data. Third, the TLM output requires verification with credible workload data to insure that it reflects reality. However, even "suspect" helicopter pilot workload data suitable for comparison with the TLM output is not available.

There is a critical need to verify the TLM output of workload values by comparing them with values obtained by other means. This is true despite the present lack of standard workload measurement techniques. "The workload problems of today will not wait until scientists develop perfect models. Fortunately, even incomplete models are useful in developing practical specifications" (Kantowitz, 1988, p.182).

C. PURPOSE AND SCOPE

The purpose of this study is to provide data that can be correlated with output from the A^3I MIDAS TLM. The study consisted of three primary procedures. First, subjective workload data was collected from subject matter experts (helicopter pilots) by means of a survey form. Next, the survey data was analyzed to develop a robust, valid set of workload values. Finally, TLM output of workload values was compared with survey workload data to determine how closely the two data sets correlated.

Chapter II of this thesis discusses the methodology used to collect subjective workload estimates from helicopter pilots. Chapters III and IV provide the data analysis techniques and results. Chapter V outlines conclusions and recommendations.

II. METHODOLOGY

A. STUDY OVERVIEW

Verifying the reliability of the TLM output was a six-step process. The data used for the study came from a survey administered to US Army helicopter pilots in a classroom environment. This method of data collection allowed for input from 71 subject-matter experts in a short time frame and at minimal expense. The six steps of the process were:

1. Identification of helicopter flight tasks for which to determine workload values.
2. Construction of survey forms which were used to collect pilot opinions about the workload levels related to these tasks.
3. Determination of data analysis procedures.
4. Administration of the surveys to Army helicopter pilots.
5. Analysis of the workload data collected via the survey.
6. Comparison of the survey data to the TLM output of workload values related to the same flight tasks.

The remainder of this chapter further explains the first four steps of the above procedure.

B. SCENARIOS AND TASKS

1. Flight Scenario Development

Flight tasks for which workload values were collected were identified through an analysis of flight missions commonly carried out by the pilots who were surveyed. Similar, but not identical, flight scenarios were developed both for attack and for scout helicopter pilots, since their missions are closely related but vary in significant ways. The scenario settings used for the survey are provided in the survey forms, examples of which are included as Appendix A (scout helicopter) and Appendix B (attack helicopter).

Each of the two scenario descriptions was developed by a pilot with experience in both the mission and the type of aircraft "flown" in the scenario. Each scenario represents approximately a two-minute slice of time from a typical attack or reconnaissance mission. Tasks occurring during the scenario are based on what a realistic cockpit crew is expected to do, under the assumption that the survey respondent is manipulating the flight controls. This creates a single-pilot situation from which consistent task workload measurements could be drawn.

2. Task Selection

The specific tasks associated with each scenario were next identified. Of the more than 20 maneuvers conducted by the pilot throughout the scenario, nine items were selected as "individual tasks," which are defined as discrete activities carried out by a pilot while flying (see Tables 1 and 2). An activity is a physical or mental process associated with a helicopter flight mission. Activities may be described by the four dimensions of human performance associated with the TLM: the visual, auditory, cognitive and motor dimensions.

Additionally, the nine individual tasks were merged into six "combined tasks," also listed in Tables 1 and 2. Combined tasks consist of discrete events that overlap along a mission time line. For example, *Tell crewmember unmasking* is one individual task and *Unmask aircraft* is another individual task. However, *Tell crewmember "Unmasking" while unmasking the aircraft* is a combined task.

Since workload levels collected via the surveys were to be compared with those generated by the MIDAS TLM, it was important that the tasks included in the survey forms consist of a potentially wide variety of workload levels. The nine individual tasks selected from the two scenarios met this requirement. As a whole, they encompassed the range of loading evaluated by the TLM. They were selected intentionally to verify all dimensions of the model, as described in Chapter I.

The nine individual tasks selected for the attack and scout helicopter pilots were exactly the same or parallel. For example, Task 4 for both groups of pilots was *Hover*. However, Task 8 for the attack helicopter pilots was *Switch master arm to "arm,"* while for the scout pilots it was *Turn up volume on ICS control panel*. Both tasks involve reaching with the left hand and adjusting a switch or knob with the fingers.

TABLE 1. ATTACK HELICOPTER FLIGHT TASKS

TASK No.	TASK CODE	INDIVIDUAL TASKS
1	Folw	Follow scout
2	Decl	NOE deceleration
3	Cktq	Check torque meter and announce reading
4	Hovr	Hover
5	Tell	Tell crewmember "Unmasking"
6	Umsk	Unmask aircraft
7	Lstn	Listen to radio transmission from scout (direction to fire, range, target)
8	Swch	Switch master arm to "arm"
9	Intp	Interpret gunner's position of TSU based on PSI information
		COMBINED TASKS
1	Cdecl	NOE deceleration behind scout
2	Ccktq	Check torque meter and announce reading while NOE decelerating
3	Cckhv	Check torque meter and announce reading while hovering
4	Cumsk	Tell crewmember "Unmasking" while unmasking aircraft
5	Clstn	Listen to radio transmission from scout (direction to fire, range, target) while switching master arm to "arm"
6	Cintp	Interpret gunner's position of TSU, based on PSI information, while receiving target handoff from scout

TABLE 2. SCOUT HELICOPTER FLIGHT TASKS

TASK No.	TASK CODE	INDIVIDUAL TASKS
1	Folw	Follow another scout
2	Decl	NOE deceleration
3	Cktq	Check torque meter and announce reading
4	Hovr	Hover
5	Tell	Tell crewchief "Unmasking"
6	Umsk	Unmask aircraft
7	Lstn	Listen to crewchief describe what he sees
8	Turn	Turn up volume on ICS control panel
9	Detm	Determine present location (6 digit grid) as crewchief holds map
		COMBINED TASKS
1	Cdecl	NOE deceleration behind another scout
2	Ccktq	Check torque meter and announce reading while NOE decelerating
3	Cckhv	Check torque meter and announce reading while hovering
4	Cumsk	Tell crewchief "Unmasking" while unmasking aircraft
5	Clstn	Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover
6	Cdetm	Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees

C. SUBJECTIVE WORKLOAD MEASUREMENT TECHNIQUES

1. Selection of Measurement Techniques

Several means of eliciting workload judgements from pilots were considered. The desired characteristics of a workload measuring mechanism were as follows:

1. *Reliable and credible results are obtained.*
2. An appropriate level of effort is required of the respondent.
3. The resulting subjective measurements can be quantified.
4. Administration to groups of 15 or more is easy.
5. Data analysis is straightforward.

Two established techniques were chosen for this study, since both met the above requirements. They were subjective workload rating scales and the psychometric technique known as Thurstone's Method of Paired Comparisons (ARI Report 851, 1989, pp.81-122). Examples of both of these techniques are included in the example survey forms located in Appendix A and Appendix B.

2. Rating Scales

Workload rating scales require the respondents to assign a numerical value (from 0 to 10 for this study) to each task, thereby indicating its level of difficulty. The use of rating scales was advocated by the designer of the MIDAS TLM, resulting from his experience with the NASA-Task Load Index (TLX) (Hart & Staveland, 1987). The TLX is a highly refined subjective workload assessment scaling technique based on rating scale methodologies. Rating scales meet the five requirements listed above for a workload measuring mechanism. They allow for any number of subjects, tolerate missing responses, and facilitate efficient statistical analysis. A potential drawback is that raters become frustrated when required to make large numbers of judgements. Thus, reducing possible frustration was a major reason for including only nine tasks on the survey form (Zatkin, 1983).

3. Thurstone's Method

Thurstone's method utilizes several judges who compare each item in a set against each of the other items, one at a time. This method results in an ordering of the items according to a relative value of magnitude interdependent on every other compared item. For the workload measurements, each pilot determined which of two compared tasks was more difficult. Judgements were made for each set of two until all individual or combined tasks had been compared with all the other individual or combined tasks. From these comparisons a scale of relative task difficulty emerged. (Thurstone, 1963)

A drawback to Thurstone's Method is the potentially cumbersome number of pairwise comparisons required of the respondent. To compare n items against each other requires $n(n-1)/2$ judgements. Workload measurements for this study required 36 comparisons of the nine individual tasks and 15 comparisons of the six combined tasks. This number of pairwise comparisons and the accompanying scale ratings provided a challenging, but not overwhelming endeavor for the pilots participating in the survey.

D. SURVEY CONSTRUCTION

1. Survey format

Two separate survey forms were used to measure helicopter pilot experience with workload during flight, one for scout helicopter pilots and the other for attack helicopter pilots (see Appendices A and B). Each was designed to be completed in approximately 15-20 minutes. The 12-page survey forms included an introduction, instructions on how the survey should be filled out, and the scenario setting. The survey itself was divided into four sections:

1. Individual task subjective rating scales.
2. Combined task subjective rating scales.
3. Individual task pairwise comparisons.
4. Combined task pairwise comparisons.

Pilot background information also was collected.

Ratings and comparisons were randomized within each section for each individual survey form. The four sections also were shuffled into their 24 different permutations, to create 24 unique formats. Rosenthal points out that "very large questionnaires can tend to discourage the subjects from answering. A way around this problem is to vary the format in order to keep the subjects interested" (Rosenthal, 1984, p.134). Besides maintaining subject interest, randomization also reduced the chances that judges might respond according to a set contextual flow of the survey material (Rosenthal, 1984).

2. Survey Content

The first page of each survey form provided background information to the pilots. Several points were highlighted:

1. The survey's purpose: attain workload information to aid in the improvement of future Army helicopter cockpits.
2. Emphasis on candid responses, with no right or wrong answers.
3. Individual anonymity and the pooling of response data.
4. The uniqueness of each survey form due to question randomizing.

These points were discussed to help control what Rosenthal calls "demand characteristic: the subject's perception of his or her role and of the experimenter's hypothesis." Clarifying the pilots' role made them more sensitive to the aims of the survey, thereby motivating a response, while instilling confidence in their ability to respond appropriately.
(Rosenthal, 1984, p.105)

The second page of the form consisted of detailed instructions indicating how to respond. Specific, relevant examples were included. This was followed by a page containing a one-paragraph scenario description providing the context within which the pilot was to respond. The setting was that of a typical tactical flight mission. Applicable parameters such as crew mix, weather conditions, and the enemy situation were described. The forms for the actual ratings and comparisons followed. The final page contained a short questionnaire regarding the aviation experiences and qualifications of the responding pilot.

The two survey forms were reviewed for accuracy of content and wording by two Army instructor pilots. They provided helpful feedback by recommending current aviation phraseology, such as changing "copilot" to "crewmember." They verified the sound structure of the scenarios and reported that the survey was appropriate for the objectives that were to be met.

3. Minimizing the Social-Desirability Response

A concept from the field of behavioral science that influenced survey construction was what is referred to as the "social-desirability response set" (Rosenthal, 1984, pp.135-139). With respect to helicopter pilots, this mindset would tend to cause them to tailor their responses so they would appear to be competent pilots who rarely experience demanding workload. Three techniques were utilized to minimize the "I can handle anything" mentality common among pilots. First, anonymity was emphasized so that no individual could be linked to a specific response. Second, the forced choices associated with Thurstone's paired comparisons required the respondent to specify that one task was harder than another. This prevented respondents from claiming that none were difficult. The third technique involved the interaction of the survey administrator with the pilots who were completing the survey, as discussed in the next section.

E. SURVEY ADMINISTRATION

1. Survey Respondents

Surveys were administered to pilots assigned to the Seventh Infantry Division (Light) located at Fort Ord, California. Pilots from the 2/9 Cavalry Squadron completed the survey on 29 March 1991. Pilots from the 1/123 Attack Helicopter Battalion completed the survey on 23 May 1991. Table 3 shows the number of respondents by category.

A third group of respondents consisted of Enlisted Aerial Observers from the same Squadron and Battalion, surveyed on the same dates. Aerial Observers are enlisted soldiers who accompany scout pilots during a mission. Although their tasks do not usually include hands-on flying, each has at least 60 hours of flight training prior to reporting to an aviation unit. As flight crewmembers working in the cockpit, they have experience with the surveyed tasks. Thus, their responses contributed a third pool of information to the data set.

TABLE 3. SURVEY RESPONDENTS

	2/9 Cavalry Sqdn	1/123 Attack Bn	Total by Group
Attack Helicopter Pilots	13	26	39
Scout Helicopter Pilots	12	6	18
Aerial Observers	8	6	14
Total by Unit	33	38	71

2. Survey Administration Procedures

The surveys were administered in a classroom environment during regularly scheduled pilot meetings. Before receiving the questionnaire, the pilots and observers were given a short briefing by the survey administrator, an Army captain. He used an overhead projector to provide necessary information to the subjects and emphasized the following:

1. The possible effect of their efforts on future aircraft design.
2. An overview of the A^3I and MIDAS systems.
3. A short discussion of human factors and its role in aircraft design.
4. Examples of survey questions and responses.

At the end of the briefing, the survey forms were distributed to the respondents by each unit's instructor pilots. All forms were completed within 15-25 minutes after distribution.

III. ANALYSIS OF STUDY DATA

A. DATA ANALYSIS SCHEME

The data collected from the 71 subjects surveyed was analyzed according to the scheme depicted in Figure 2. The

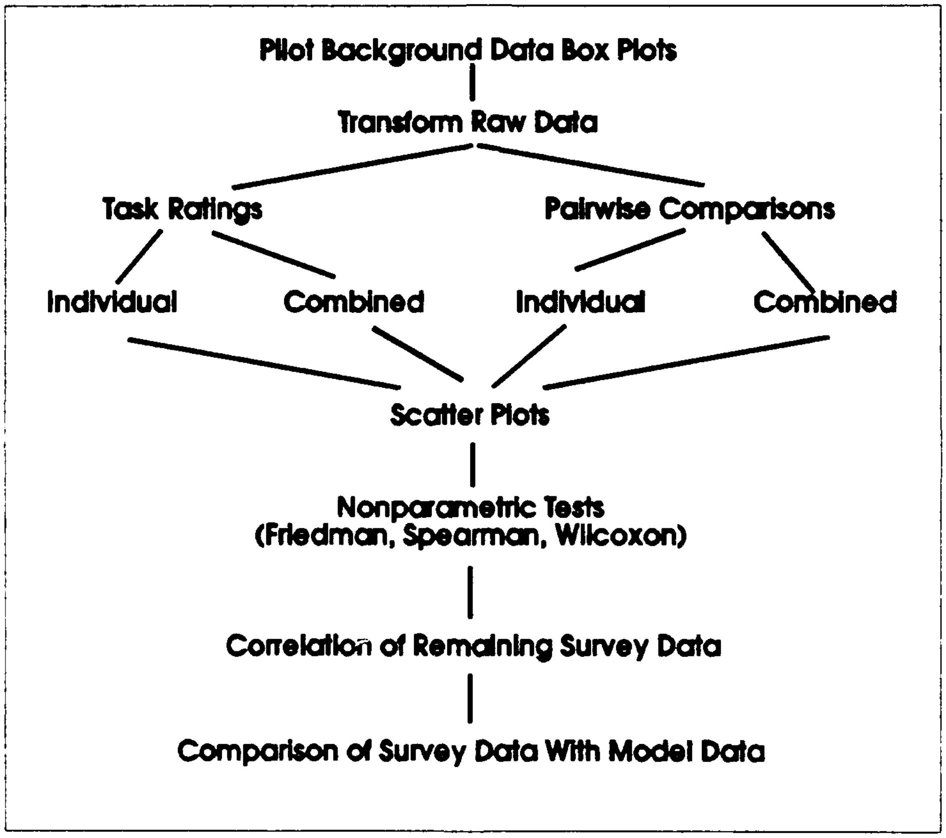

Figure 2. Data Analysis Scheme

concepts guiding the analysis were:

1. Determine the degree of homogeneity among the respondents.

2. Attain workload values for the tasks evaluated by the six groups of subjects from a Cavalry Squadron and an Attack Helicopter Battalion, each consisting of attack helicopter pilots, scout helicopter pilots, and aerial observers.

3. Filter the groups of data by means of nonparametric statistical tests.

4. Accept a final pool of workload measurements that meet the above criteria.

These concepts were utilized to provide an internally consistent set of study data.

B. PILOT BACKGROUND INFORMATION

The last page of the workload survey consisted of questions intended to establish each subject's aviation background and experience (see Appendix A or B). The pilot background data was graphically analyzed using Box plots (Rice, 1988, pp.336-337) in order to compare the aviators in the 2/9 Cavalry Squadron with those of the 1/123 Attack Helicopter Battalion. Three particular measures were analyzed:

1. Total flight time.

2. Flight time in the aviator's primary aircraft: either the attack helicopter or the observation helicopter.

3. Flight time as a pilot-in-command.

Figure 3 shows a multiple Box plot of the total flight time of all the subjects. The first plot represents the attack helicopter pilots of the Attack Battalion (AH-AB) alongside those of the Cavalry Squadron (AH-CV) in the second plot. The third and fourth plots (SH-AB and SH-CV) are those of the Scout pilots. The two groups of observers (EO-AB and EO-CV) are plotted last.

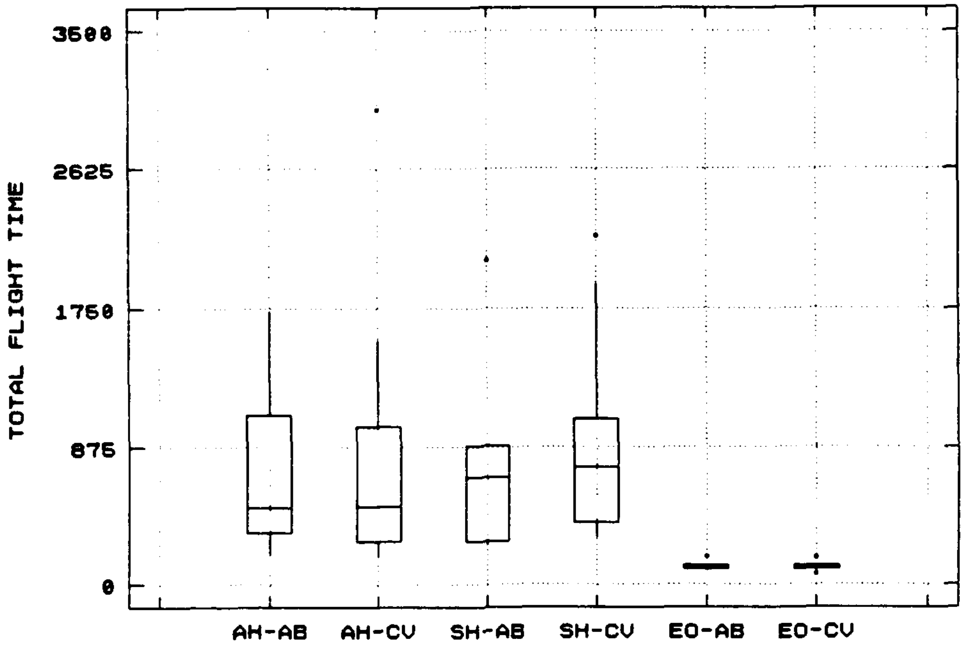

Figure 3. Multiple Box Plots of Grouped Aviator Total Flight Time

These Box plots provide an efficient method of analysis for several groups of data. Several observations can be made, based on the complete set of Box plots analyzed during this study. These observations include the following:

1. When grouped within their respective units, the attack helicopter pilots of the Cavalry Squadron and Attack Battalion have very similar backgrounds in total flight time, attack helicopter flight time, and pilot-in-command flight time.

2. There was one attack helicopter pilot outlier, a pilot in the Cavalry Squadron with almost 3000 hours of total flight time.

3. The grouped scout helicopter pilot data indicated that subjects from the Cavalry Squadron averaged approximately 100 hours more experience in the three flight time categories than those from the Attack Battalion.

4. Each scout helicopter unit had one outlier with slightly more than 2000 hours total flight time.

5. Only total flight time data was analyzed for the enlisted aerial observers. Box plots for observers from both units are almost identical.

C. DATA TRANSFORMATION AND SUMMARIZATION

The data collected on the survey forms was transformed into 24 response vectors of either six or nine values. Each vector was derived from grouped subject responses for either the individual or combined task data from the rating scales or paired-comparisons. In other words, these 24 vectors represented responses from the six aviator groups for the four sections of the survey.

The rating scale responses were transferred from each survey form to a spreadsheet. There they were recorded, summed, and averaged. The resultant values are listed in Table 4, where smaller values denote lower workload levels. The paired comparison responses were transferred from the survey forms into pooled groups of workload values by means of Thurstone's Method (Thurstone, 1963, pp. 67-81). The particular method used, Thurstone's Case V (Dunn-Rankin, 1983, pp. 79-82), resulted in the values listed in Table 5.

TABLE 4. INITIAL AVERAGE TASK RATING WORKLOAD VALUES

INDIVIDUAL TASKS						
	Attack Pilots		Scout Pilots		Observers	
Group Code	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
Task No.	Attack Bn	Cav Sqdn	Attack Bn	Cav Sqdn	Attack Bn	Cav Sqdn
1	3.87	4.19	2.17	2.08	2.83	4.19
2	3.40	3.46	2.50	2.75	3.83	4.69
3	2.33	2.38	1.17	1.58	2.83	2.19
4	2.56	2.81	2.17	1.83	2.17	2.81
5	1.13	0.88	0.67	0.83	0.58	1.31
6	2.67	3.77	1.83	2.25	2.33	3.06
7	3.29	3.38	1.00	2.42	1.83	2.19
8	2.06	2.58	2.33	2.00	1.33	1.56
9	3.42	2.92	5.50	5.92	4.50	6.56
COMBINED TASKS						
1	2.33	4.85	4.29	3.58	4.83	4.69
2	3.83	4.85	4.17	4.75	5.50	5.56
3	1.33	2.62	2.63	1.42	3.50	1.69
4	0.50	1.62	2.10	1.33	1.67	1.56
5	3.17	4.00	4.13	3.08	4.33	3.19
6	5.50	4.35	4.94	5.58	5.83	5.44
n	26	13	6	12	6	8

TABLE 5. INITIAL AVERAGE PAIRED-COMPARISON WORKLOAD VALUES

INDIVIDUAL TASKS						
	Attack Pilots		Scout Pilots		Observers	
Group Code	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
Task No.	Attack Bn	Cav Sqdn	Attack Bn	Cav Sqdn	Attack Bn	Cav Sqdn
1	1.93	2.77	2.90	1.25	1.97	1.47
2	1.82	2.45	2.90	1.59	2.44	1.66
3	1.13	0.87	1.40	0.27	1.78	0.55
4	1.41	1.14	1.91	0.89	1.72	0.57
5	0.00	0.00	0.00	0.00	0.00	0.00
6	1.59	1.76	2.28	1.19	1.88	0.46
7	1.68	2.14	1.19	0.93	0.93	0.31
8	1.23	1.68	2.06	0.91	1.03	0.54
9	1.54	1.77	3.99	2.82	2.74	2.42
COMBINED TASKS						
1	1.51	1.75	2.48	1.87	1.08	1.08
2	2.08	2.12	2.49	1.95	2.80	1.39
3	0.53	0.77	1.00	0.30	0.78	0.00
4	0.00	0.00	0.00	0.00	0.00	0.09
5	1.39	2.18	2.26	1.72	0.85	1.39
6	1.75	2.60	3.43	2.33	2.88	1.89
n	26	13	6	12	6	8

The workload values listed in Tables 4 and 5 are characterized as follows:

1. Group codes, identifying columns of workload values, correspond with the similarly-labelled graphic data for the Squadron and Battalion used throughout this study (See Figure 3).

2. Tasks are listed in order of their occurrence during the flight scenario.

3. The greater the workload value, the more difficult the task.

4. Thurstone's method assigns the easiest task the value zero. Higher-valued tasks are assigned a quantitative workload measure according to their relative difficulty in relation to the other tasks.

5. The bottom row in each table indicates the number of respondents, n, whose responses were used to calculate each column's workload values.

These 24 vectors of workload data provide the input for the subsequent analysis and tests to follow.

D. PLOTS OF WORKLOAD DISTRIBUTION

Plots of the workload data in Tables 4 and 5 provided a quick graphic assessment of the distribution of workload according to task (Chambers, 1983, pp. 82-86). Most of the plots constructed for the study compared the responses of one group of aviators from the Cavalry Squadron with those in the same type of group from the Attack Helicopter Battalion. Three representative graphs are depicted in Figures 4, 5, and 6.

Figure 4 shows the plot of individual-task paired-comparison workload values for the attack helicopter pilots in both the Cavalry Squadron and the Attack Helicopter Battalion. Figure 5 shows combined-task paired-comparison workload data for the scout pilots of both units. Figure 6 shows a plot of all of the individual task ratings provided by all subjects,

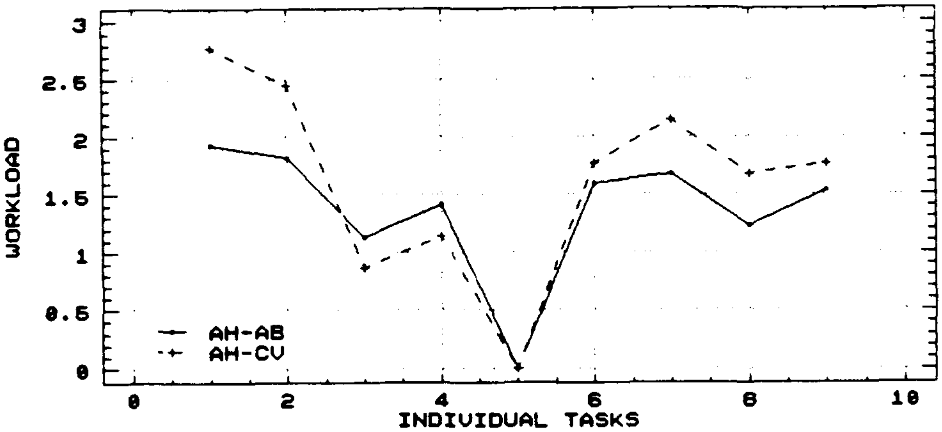

Figure 4. Plot of Attack Helicopter Pilot Workload Measurements Based on Individual-Task Paired Comparisons

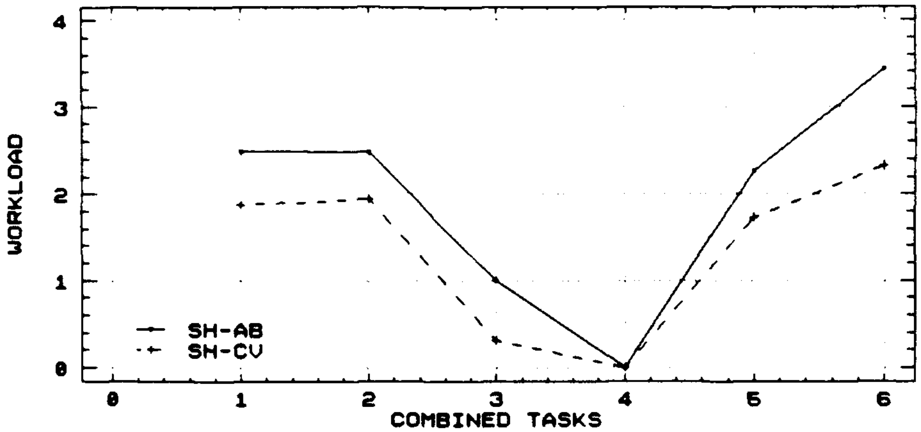

Figure 5. Plot of Scout Helicopter Pilot Workload Measurements Based on Combined-Task Paired Comparisons

averaged according to their six respective aviator and unit groups. All three plots indicate that there is a general trend toward like responses among the groups of aviators.

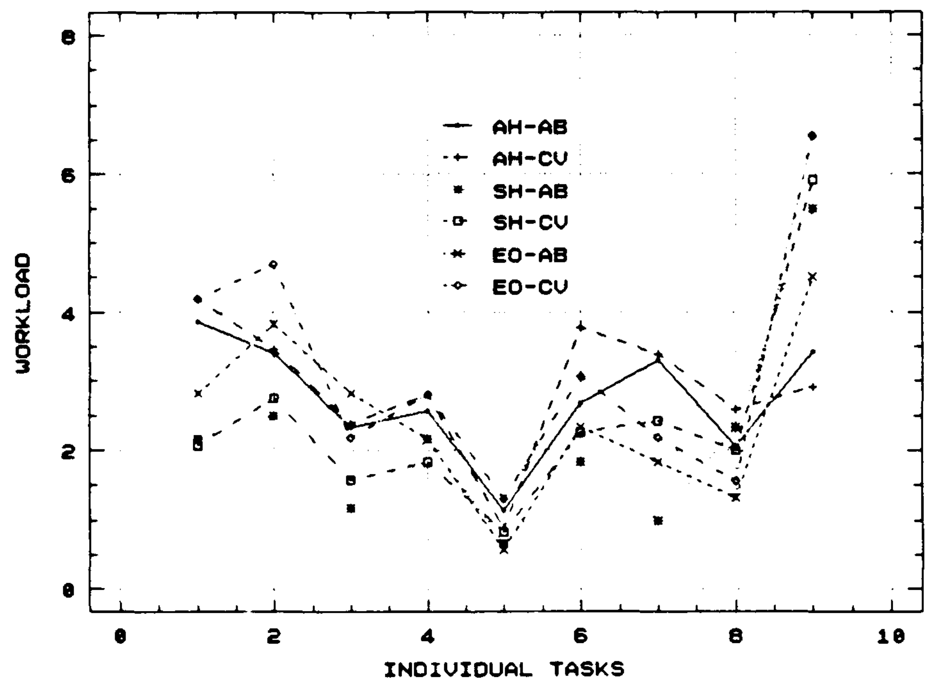

Figure 6. Plot of Aviator Workload Measurements Based on Individual Task Ratings by All Study Participants

E. NONPARAMETRIC TESTS

Several nonparametric statistical tests of the data were employed to investigate possible trends and to determine if responses were consistent among the subjects. These tests were used to explore the validity of combining the workload data vectors into fewer pools of data, with more respondents contributing to each pool.

1. Friedman Test

The Friedman test for randomized block designs (Mendenhall, 1990, pp. 702-704) was used to determine if the responses of each pilot grouping came from identical distributions. The significance level for this test was set at 0.05. Thus, if the groups tested attained a *p* value greater than 0.05, then they would be considered to come from the same underlying distribution.

Friedman tests were conducted on data for each of the four sections of the survey. Individual- and combined-task ratings and paired comparisons for each of the six aviator groups were tested as randomized blocks. Figure 7 graphically portrays the Friedman Test results for one section of the survey, the individual-task paired comparisons. The varying bar lengths indicate that the six groupings appear to differ in the average of the ranks given to workload values. This is numerically supported by the *p* value of 0.0001 obtained from the Friedman test for this randomized block.

Similar results were found for initial average workload values from the other three survey sections. Table 6 shows the *p* values for data from all four sections. Thus, for each of the four sections, it cannot be assumed that all six groups of respondents are from the same underlying distribution. Therefore, all six response vectors should not be combined into one data pool for any of the four survey sections, as none of the *p* values exceeded 0.05.

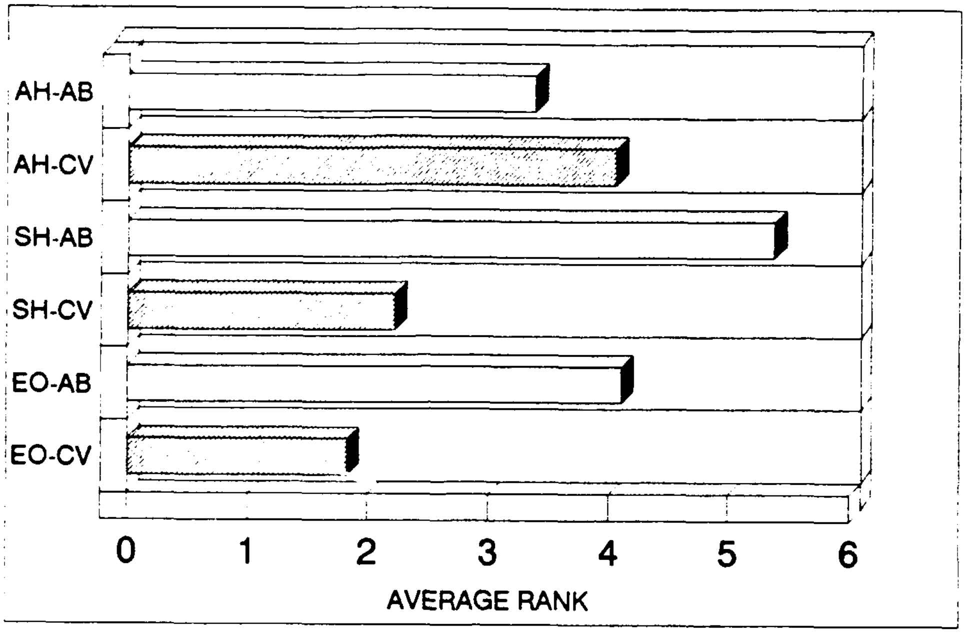

Figure 7. Friedman Test Average Ranks of Aviator Groups for the Individual Task Paired-Comparisons

TABLE 6. FRIEDMAN TEST P VALUES

SECTION	*P* VALUE	IMPLICATION
Individual Task Ratings	0.0071	Do not pool data from top half TABLE 4
Combined Task Ratings	0.0114	Do not pool data from bottom half TABLE 4
Individual Task Paired Comparisons	0.0001	Do not pool data from top half TABLE 5
Combined Task Paired Comparisons	0.0448	Do not pool data from bottom half TABLE 5

2. Spearman Rank Correlations

Since the Friedman test indicated that the data could not be combined into one data pool, Spearman rank correlations (Hamburg, 1987, pp. 576-578) were utilized to determine if data from any of the four sections could be pooled for any of the six aviator groups. Comparisons were made between like aviators of the Attack Battalion and the Cavalry Squadron. For example, the responses of the attack pilots of the Attack Helicopter Battalion (AH-AB) were correlated with those of the Cavalry Squadron (AH-CV) attack pilots. The significance level of 0.006 (shown in the upper left portion of Table 7) indicates a high degree of correlation between these two groups of responses.

Of the groups of aviators, those that correlated with a significance level less than 0.05 were considered to be candidates for data pooling. Table 7 shows the significance levels associated with the Spearman rank correlations of the six aviator groups for the individual-task paired comparisons. Only the correlations of like groups (those performing similar missions) are included. Additionally, scout pilot and enlisted observer comparisons were only made when the two groups were in the same unit. For instance, the responses of the Cavalry Squadron Observers (EO-CV) were correlated only with Cavalry Squadron scout pilots (SH-CV), not with Attack

Battalion scouts (SH-AB). However, cross unit observer comparisons were made (EO-AB with EO-CV).

The results of the Spearman rank correlations for individual-task paired comparisons are more favorable to data pooling than are results obtained for data from the other survey sections (significance levels for the Spearman rank correlations of the other three sections of the survey are located in Appendix C). The **bold** numbers indicate groups whose correlations are statistically significant (i.e., less than 0.05).

TABLE 7. RANK CORRELATION SIGNIFICANCE LEVELS

INDIVIDUAL-TASK PAIRED COMPARISONS						
	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
AH-AB	-	**0.006**	-	-	-	-
AH-CV		-	-	-	-	-
SH-AB			-	**0.011**	**0.009**	-
SH-CV				-	-	**0.048**
EO-AB					-	**0.013**
EO-CV						-

Figure 8 is a graph of the Spearman rank correlations for the five comparisons of data from the individual-task paired comparisons where correlations are statistically acceptable for pooling (AH-CV and AH-AB, SH-CV and SH-AB, SH-

AB and EO-AB, SH-CV and EO-CV, and EO-AB and EO-CV). These five comparisons correspond with the five bold significance levels in Table 7. The Spearman test results (low significance levels and high correlations) for these five group comparisons indicates similar underlying distributions for each pair and suggests that pooling may be appropriate.

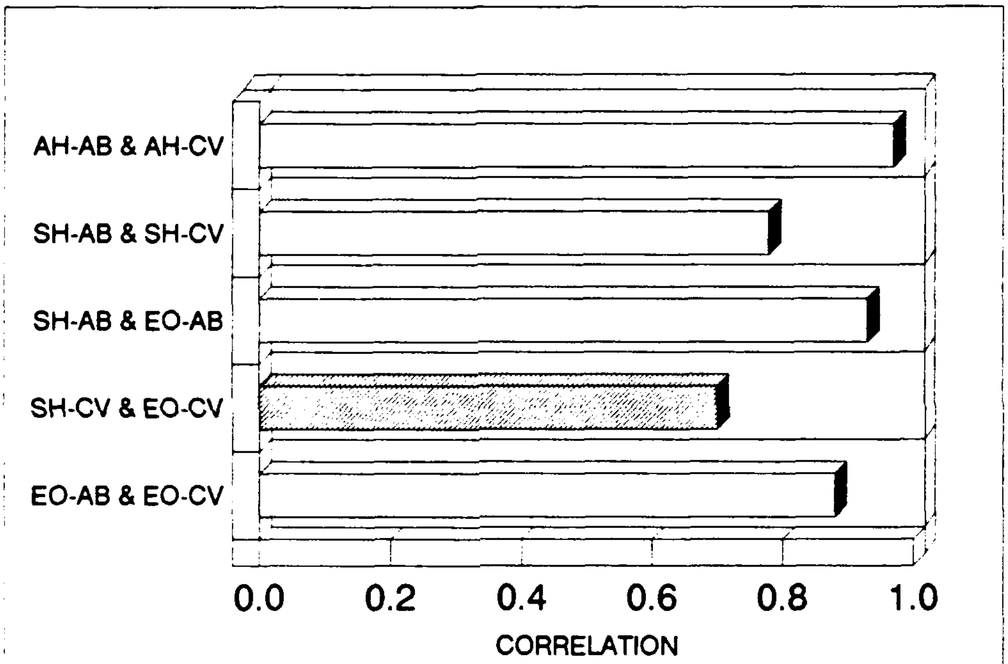

Figure 8. Spearman Rank Correlations for the Individual-Task Paired Comparisons

3. Wilcoxon Signed Rank Test

Before accepting the groupings of data suggested by the Spearman test, a final nonparametric test was conducted.

The Wilcoxon signed rank test (Mendenhall, 1990, pp. 680-681) provided a method of determining the sameness or difference of the aviator workload response distributions. The same aviator group comparisons made during the Spearman test were made with the Wilcoxon test. The *p* values generated by the Wilcoxon test are listed in Table 8 for the task ratings and in Table 9 for the paired comparisons. *P* values greater than a significance level of 0.05 imply that the underlying distributions are similar. Values in this category are printed in **bold** type.

TABLE 8. WILCOXON SIGNED RANK TEST RESULTS FOR THE TASK RATINGS OF CORRELATED GROUPS

	INDIVIDUAL TASKS		*COMBINED TASKS*	
Compared Groups	No. of Pairs	*p* value	No. of pairs	*p* value
AH-AB & AH-CV	9	**0.17**	6	**0.21**
SH-AB & SH-CV	9	**0.16**	6	**0.14**
EO-AB & EO-CV	9	0.03	6	**0.06**
SH-AB & EO-AB	9	**0.44**	6	**0.09**
SH-CV & EO-CV	9	0.02	6	**0.09**

Tables 9 and 10 show the following:

1. Workload values may be pooled for both the individual- and combined-task ratings for AH-AB & AH-CV, SH-AB & SH-CV, and SH-AB & EO-AB.

TABLE 9. WILCOXON SIGNED RANK TEST RESULTS FOR THE PAIRED COMPARISONS OF CORRELATED GROUPS

Attack Bn/Cav Sqdn Samples	INDIVIDUAL TASKS		COMBINED TASKS	
	No. of Pairs	*p* value	No. of pairs	*p* value
AH-AB & AH-CV	9	**0.14**	6	**0.06**
SH-AB & SH-CV	9	0.01	6	**0.06**
EO-AB & EO-CV	9	0.01	6	**0.28**
SH-AB & EO-AB	9	0.04	6	**0.18**
SH-CV & EO-CV	9	**0.11**	6	**0.06**

2. Workload values may be pooled for only the combined-task ratings for EO-AB & EO-CV and SH-CV & EO-CV.

3. Workload values may be pooled for both the individual- and combined-task paired comparisons for AH-AB & AH-CV and SH-CV & EO-CV.

4. Workload values may be pooled for only the combined-task paired comparisons for SH-AB & SH-CV, EO-AB & EO-CV, and SH-AB & EO-AB.

Results obtained from the Wilcoxon signed rank test indicate that other values cannot be pooled. The test showed that the underlying distributions were not the same.

F. POOLED WORKLOAD RESPONSES

Pooled workload values resulting from the filtering effect of the nonparametric tests are listed in Table 10 for the task ratings and Table 11 for the paired comparisons. The data in Tables 10 and 11 represents the highest level of pooling that can be justified by the nonparametric tests. In other words, data from the groups of aviators was pooled as shown in Tables

10 and 11 if the Spearman test and the Wilcoxon test significance level values are shown in bold type in both Table 7 (or Appendix C) and Table 8 or 9.

The values listed in Tables 10 and 11 were generated by recomputing the raw data from the survey forms. The recomputations involved transforming the pooled aviator response data into appropriate task ratings and Thurstone paired-comparison values. This process was carried out only for data groups shown in Tables 4 and 5 which were highly correlated according to the Spearman test, and were determined to be of the same underlying distribution by the Wilcoxon test. Data that did not meet these requirements was not included in Tables 10 and 11. Thus, four columns in Table 10 and four columns in Table 11 are blank.

Absent from Tables 10 and 11 are pooled workload values for the enlisted aerial observers (EO-AH and EO-CV). As these aviators are not qualified pilots, their responses considered alone may not accurately portray workload. Therefore, the observers' responses were included in Tables 10 and 11 only when they agreed with those of the scout pilots, according to the Spearman and Wilcoxon tests. The pooled workload values of the two right hand columns of Tables 10 and 11 include responses from the enlisted aerial observers pooled with those of the scout pilots.

TABLE 10. POOLED AVERAGE TASK RATING WORKLOAD VALUES

INDIVIDUAL TASKS				
Group Code	AHR	SHR	SOR-AB	SOR-CV
Task No.	All Attack Pilots	All Scout Pilots	Attack Bn Scout & Obser	Cavalry Sqdn Scout & Obser
1	3.97	Cannot be pooled according to Spearman Test	Cannot be pooled according to Spearman Test	Cannot be pooled according to Wilcoxon Test
2	3.42			
3	2.35			
4	2.64			
5	1.05			
6	3.04			
7	3.32			
8	2.23			
9	3.26			
COMBINED TASKS				
1	Cannot be pooled according to Spearman Test	3.17	3.58	4.03
2		4.44	4.67	5.08
3		1.39	2.42	1.52
4		1.06	1.08	1.43
5		3.11	3.75	3.13
6		5.56	5.67	5.53
n	39	18	12	20

TABLE 11. POOLED AVERAGE PAIRED-COMPARISON WORKLOAD VALUES

INDIVIDUAL TASKS				
Group Code	AHP	SHP	SOP-AB	SOP-CV
Task No.	All Attack Pilots	All Scout Pilots	Attack Bn Scout & Obser	Cavalry Sqdn Scout & Obser
1	2.03	Cannot be pooled according to Wilcoxon test		1.32
2	1.87			1.58
3	0.96			0.41
4	1.28			0.78
5	0.00			0.00
6	1.55			0.94
7	1.69			0.69
8	1.28			0.81
9	1.50			2.64
COMBINED TASKS				
1	Cannot be pooled according to Spearman test	1.99	0.93	Cannot be pooled according to Spearman test
2		1.99	1.02	
3		0.50	0.07	
4		0.00	0.00	
5		1.72	0.94	
6		2.51	1.35	
n	39	18	12	20

G. CORRELATION OF RATINGS WITH PAIRED-COMPARISONS

Spearman's rank correlations were used with the pooled data of Tables 10 and 11 to verify the internal consistency of aviator responses. Workload ratings for the individual and combined tasks were compared with the paired-comparison workload values for the same tasks for those cases where both Table 10 and Table 11 had data in the same columns.

For the individual tasks the only correlation that met this requirement was that for the attack helicopter pilots. The significance level of 0.007 for the Spearman correlation of all attack helicopter pilot individual-task workload ratings (AHR, Table 10) with related paired-comparison workload values (AHP, Table 11) indicates consistent attack helicopter pilot responses throughout the survey for these tasks.

Combined-task workload values from Tables 10 and 11 also were tested. Table 12 provides the significance levels found for the Spearman correlations. Only scout helicopter pilot and enlisted aerial observer response data are included, as the attack helicopter pilot responses could not be pooled. All values in Table 12 are below the 0.05 significance level, suggesting consistency in the scout and observer responses for the combined tasks.

Results of the nonparametric tests prevented pooling of scout helicopter pilot individual task responses for the Attack Helicopter Battalion and the Cavalry Squadron. Thus Spearman correlations were performed on the initial workload values for the individual tasks of the scout helicopter pilots (Tables 4 and 5). Attack Battalion scout pilots' individual-task ratings (SH-AB, Table 4) and paired-comparisons (SH-AB, Table 5) correlated with a significance level of 0.013. Cavalry Squadron scout pilots' individual-task ratings (SH-CV, Table 4) and paired comparisons (SH-CV, Table 5) correlated with a significance level of 0.008. As with the pooled observations above, the significance levels for correlation between the two kinds of initial workload values indicates consistency among the aviators' responses.

TABLE 12. RANK CORRELATION SIGNIFICANCE LEVELS FOR POOLED WORKLOAD VALUES

COMBINED TASKS: RATINGS AND PAIRED COMPARISONS					
	SHR	SOR-AB	SOR-CV	SHP	SOP-AB
SHR	-	**0.035**	**0.000**	**0.028**	**0.035**
SOR-AB		-	**0.035**	**0.045**	**0.000**
SOR-CV			-	**0.028**	**0.035**
SHP				-	**0.045**
SOP-AB					-

Nonparametric test results also prevented pooling of attack helicopter pilot combined-task responses for the Attack Helicopter Battalion and the Cavalry Squadron. Thus, as with the scout pilot comparisons above, Spearman correlations were performed on the initial workload values (Tables 4 and 5). Attack Battalion attack pilots' combined-task ratings (AH-AB, Table 4) and paired comparisons (AH-AB, Table 5) correlated with a significance level of 0.048. Cavalry Squadron attack pilots' combined-task ratings (AH-CV, Table 4) and paired comparisons (AH-CV, Table 5) correlated with a significance level of 0.243. From these correlations, the Attack Battalion attack pilots' combined-task workload values are consistent for the ratings and the paired comparisons. However, the high significance level (0.243) for the Cavalry Squadron does not support consistency between the responses to the ratings and the paired comparisons.

For the correlations of the task rating workload values with the paired-comparison workload values, low significance levels indicate high correlations. The results discussed above show that the subjects' responses were consistent throughout the survey. Furthermore, test results confirm robustness of the data and a high degree of reliability among the selected groups of responses. Based on these tests, the data in Tables 10 and 11 and selected values of Tables 4 and 5 (except for Cavalry Squadron attack helicopter pilot responses) can be confidently used as baseline workload values for the tasks and conditions considered. These baseline, empirically-determined values serve as "ground truth" data that can be used to validate the Midas Task Loading Model's analytically-produced values for the same tasks.

IV. COMPARISON OF MIDAS MODEL DATA WITH STUDY DATA

A. TASK LOADING MODEL WORKLOAD VALUES

The MIDAS TLM generates workload data at a higher resolution than was measured by the survey forms. The TLM measures workload along four dimensions of human performance. These dimensions are the visual, auditory, cognitive, and motor activities performed by an aviator while flying. In its present configuration, the TLM averages workload values generated along each of the four dimensions for each of the individual and combined tasks. The tasks modelled in the TLM are comparable to the nine individual tasks and six combined tasks used in the pilot survey. The result is a set of task workload values as listed in Table 13. The numbers represent relative workload on a scale of 0 to 100, with larger numbers indicating higher workload. (Staveland, 1990, pp.6-9)

Two different techniques were used with the TLM system to create workload values for the scout and attack helicopter pilot tasks. The first technique involved measuring only the workload generating attributes of the human performance dimensions involved in a task beyond the activity of flying. That is, only workload related to human performance above the basic activity of flying was calculated. This technique generated the first two columns of data in Table 13 (ATK and SCT). The second technique combined the workload attributes of a task with an underlying activity of basic flying. Thus

TABLE 13. TLM-GENERATED WORKLOAD VALUES

INDIVIDUAL TASKS				
Group Code	ATK	SCT	BSCATK	BSCSCT
Task No.	Attack Pilots	Scout Pilots	Attack Pilots (Basic)	Scout Pilots (Basic)
1	29	29	45	45
2	27	27	42	42
3	27	27	42	42
4	26	26	42	42
5	18	18	44	44
6	26	26	42	42
7	16	13	47	46
8	19	34	36	54
9	33	32	30	46
COMBINED TASKS				
1	30	30	46	46
2	60	60	42	42
3	57	57	44	44
4	47	47	46	46
5	45	39	42	50
6	56	53	52	53

the workload of each task included the supposition of an ongoing basic hands-on flying activity. This technique generated the last two columns of data in Table 13 (BSCATK and BSCSCT). (Staveland, 1990, pp.19-23)

From a visual inspection of the data in Table 13, it appears that the TLM-generated values for attack and scout pilots are similar in columns ATK and SCT and in columns BSCATK and BSCSCT, respectively. Except for tasks 7 and 8, the TLM values indicate that the scout and attack helicopter pilots should experience almost identical levels of workload for a given task. An additional observation is that many tasks within a column of data have identical or near identical workload values. For example, the individual-task portion of column BSCSCT contains four workload measurements of 42, two of 46, and one each of 44 and 45. According to the TLM model results, eight out of nine tasks involve essentially the same amount of workload.

B. RANK CORRELATION OF MODEL DATA WITH SURVEY DATA

The TLM model-generated workload values were compared with the survey workload values in a procedure similar to that described in Chapter III, Section G, where the task ratings were correlated with the paired comparisons using the Spearman rank correlation technique. The survey workload values used for this correlation are from Tables 4, 5, 10, and 11. The model data used is all from Table 13.

The results of the Spearman rank correlation technique are provided in Tables 14 to 17. Each of the first four tables corresponds to one of the four sections of the survey. Tables 18 and 19 show the results of correlating the TLM with itself. Significance levels below 0.05, printed in **bold** type, indicate high correlation.

TABLE 14. RANK CORRELATION SIGNIFICANCE LEVELS OF MODEL VERSUS STUDY WORKLOAD VALUES, FOR ATTACK HELICOPTER INDIVIDUAL TASKS

TLM Group Code	Survey Group Code	
	AHR	AHP
ATK	0.183	0.358
BSCATK	0.403	0.408

TABLE 15. RANK CORRELATION SIGNIFICANCE LEVELS OF MODEL VERSUS STUDY WORKLOAD VALUES, FOR SCOUT HELICOPTER INDIVIDUAL TASKS

TLM Group code	Survey Group Code			
	SH-AB (ratings)	SH-CV (ratings)	SH-AB (comparisons)	SH-CV (comparisons)
SCT	**0.027**	0.521	**0.049**	0.225
BSCSCT	0.628	0.504	0.852	0.604

The following observations may be made from the six tables:

1. No significant correlations were found for the attack helicopter individual or combined tasks (Tables 14 and 16) nor the scout helicopter combined tasks (Table 17).

2. Two significant correlations were found for the scout helicopter individual tasks (Table 15). The TLM's scout workload values were strongly correlated with both the ratings and paired-comparison values from the Attack Battalion scout pilots' (SH-AB). However, only six scout pilots contributed to these two categories of survey data.

TABLE 16. RANK CORRELATION SIGNIFICANCE LEVELS OF MODEL VERSUS STUDY WORKLOAD VALUES, FOR ATTACK HELICOPTER COMBINED TASKS

TLM Group Code	Survey Group Code			
	AH-AB (ratings)	AH-CV (ratings)	AH-AB (comparisons)	AH-CV (comparisons
ATK	0.565	1.000	0.482	0.949
BSCATK	1.000	0.841	0.844	1.000

TABLE 17. RANK CORRELATION SIGNIFICANCE LEVELS OF MODEL VERSUS STUDY WORKLOAD VALUES, FOR SCOUT HELICOPTER COMBINED TASKS

TLM Group Code	Survey Group Code				
	SHR	SHP	SOR-AB	SOR-CV	SOP-AB
SCT	0.655	0.897	0.565	0.655	0.565
BSCSCT	0.604	0.490	0.476	0.604	0.476

3. The significance levels for TLM-survey data correlations for both the scout and attack helicopter combined tasks (Tables 16 and 17) were generally poorer than those for the individual tasks (Tables 14 and 15). This indicates that the workload results obtained via both techniques for individual tasks correlated somewhat better than did those for the combined tasks.

4. The significance level values in Tables 18 and 19 indicate that the TLM's two workload measurement techniques do not correlate highly with each other.

TABLE 18. RANK CORRELATION SIGNIFICANCE LEVELS OF TLM INDIVIDUAL TASK WORKLOAD VALUES

TLM Group Code	TLM Group Code	
	BSCATK	BSCSCT
ATK	0.233	-
SCT	-	0.307

TABLE 19. RANK CORRELATION SIGNIFICANCE LEVELS OF TLM COMBINED TASK WORKLOAD VALUES

TLM Group Code	TLM Group Code	
	BSCATK	BSCSCT
ATK	0.554	-
SCT	-	0.218

C. GRAPHIC ANALYSIS OF MODEL DATA AND SURVEY DATA

1. Data Selection for Further Analysis

Several graphic plots were prepared to make further comparisons between results from the two workload measuring devices. All of the survey data used for the graphic analysis came from the workload task ratings data, based on a scale of 0 to 10. With a minor transformation, these values were directly comparable to the TLM output, which was based on a scale of 0 to 100. Survey data used for the graphic comparisons included AHR (Table 10, top) for the attack helicopter individual tasks, SH-CV (Table 4, top) for the scout helicopter individual tasks, AH-AB (Table 4, bottom) for the attack helicopter combined tasks, and SHR (Table 10, bottom) for the scout helicopter combined tasks.

The four task-rating data vectors utilized for the graphic comparisons (AHR, SH-CV, AH-AB, and SHR) have been shown to be robust and internally valid for use as baseline workload values (Chapter III, Section G). An additional criterion for the survey data used for the comparisons was that these vectors contained workload values from the greatest number of respondents for a given survey section. For example, the SH-CV vector (Table 4, top) was chosen over SH-AB (Table 4, top) because SH-CV represented responses from 12 participants while SH-AB values were obtained from only six participants.

2. Results of Analysis

The nine workload plots included in this section are based on a workload scale ranging from 0 to 100. Smaller values represent lower workload values. Survey data is plotted with a solid line in each graph. Model-generated data is plotted with a dashed line. Due to its demonstrated validity and robustness, the survey data has been taken as "ground truth" for these comparisons.

The first plot, Figure 9, shows the only set of model-generated (SCT) and survey (SH-AB) workload values that correlated with a significance level below 0.05. Distinct differences in workload across the tasks may be observed. The model data generally tracks values from the survey data; however, the model data's "flatness" implies that it may have poorer resolution in measuring workload levels. Nevertheless, considering the high data correlation, Figure 9 serves as a base from which to view the other graphs.

The remaining eight graphs are characterized by the following observations:

1. Figure 10 shows that the attack helicopter individual-task model data (ATK) agrees reasonably well with the associated survey data (AHR). Primary differences are for Task 1 (*Follow scout*) and Task 7 (*Listen to radio transmission*).

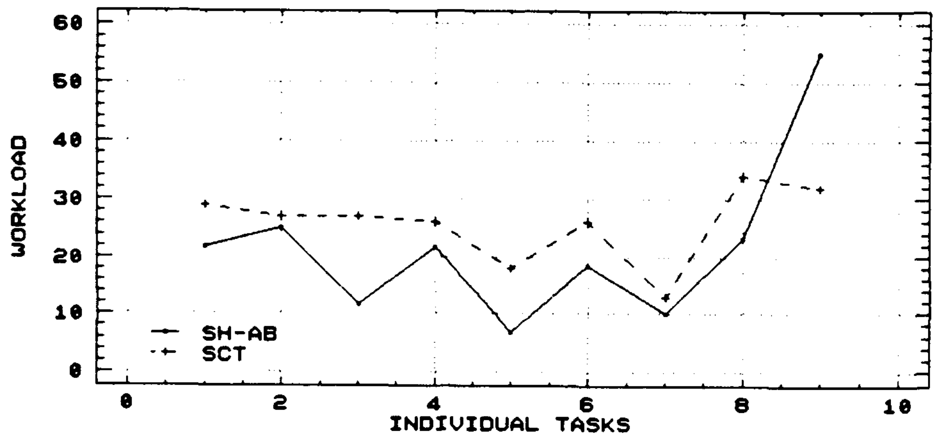

Figure 9. Highly Correlated Scout Helicopter Model (SCT) and Survey (SH-AB) Workload Values

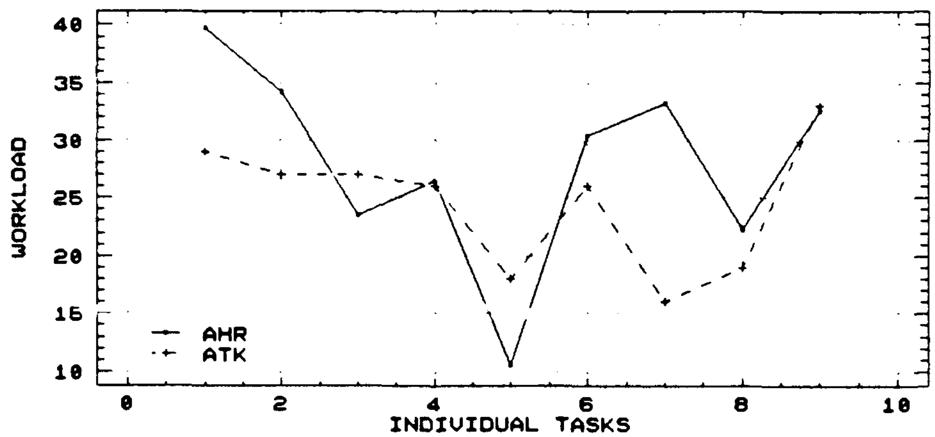

Figure 10. Attack Helicopter Model (ATK) and Survey (AHR) Workload Values

2. Figure 11 indicates that the TLM BSCATK data over-estimates workload and provides little resolution for attack helicopter individual tasks.

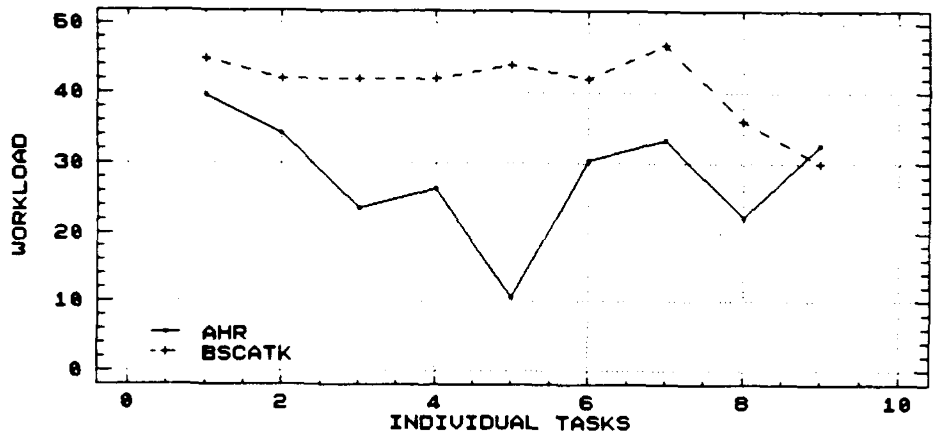

Figure 11. Attack Helicopter Model (BSCATK) and Survey (AHR) Workload Values

3. Figure 12 is very similar to Figure 9. The survey data of Figure 12 comes from the Cavalry Squadron scout pilots (SH-CV). The survey data of Figure 9 comes from the Attack Battalion scout pilots (SH-AB). Comparing Figure 9 with Figure 12, it may be seen that the model provides a slightly better measure of Attack Battalion scout pilot workload than Cavalry Squadron workload. The major discrepancy is for Task 7 (*Listen to radio transmission*).

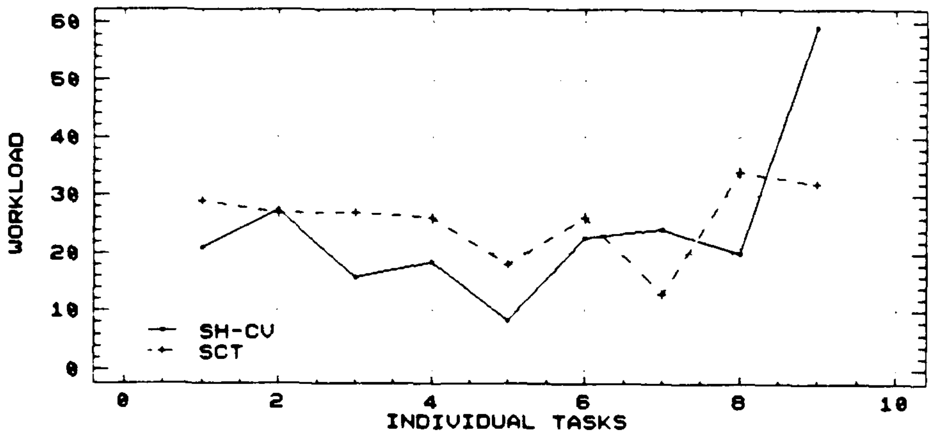

Figure 12. Scout Helicopter Model (SCT) and Survey (SH-CV) Workload Values

4. Figure 13 is similar to Figure 11. Again, the BSCSCT data overestimates workload and provides little resolution for scout helicopter individual tasks.

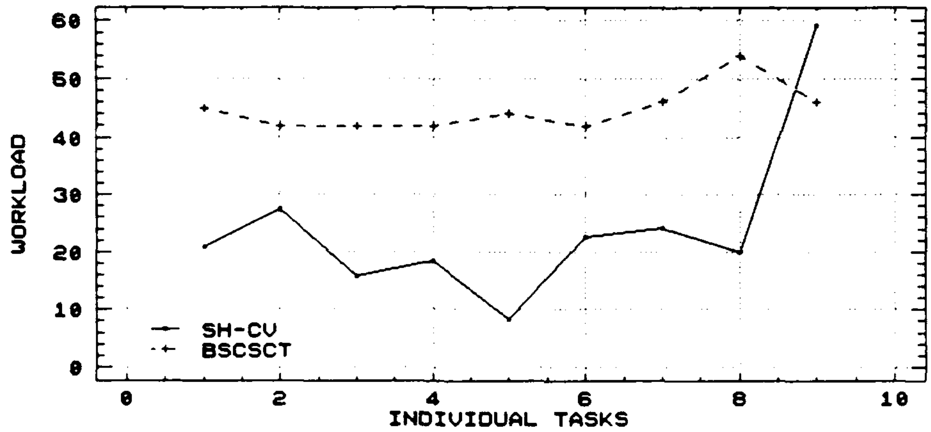

Figure 13. Scout Helicopter Model (BSCSCT) and Survey (SH-CV) Workload Values

5. Figures 14 through 17 all involve combined tasks and display similar results. In each case the model-generated workload values are much higher than the survey values for most tasks. The model values for ATK (Figure 14) and SCT (Figure 16) show some trend agreement with the survey values, but greatly overestimate all but the first and last tasks. The model's BSCATK (Figure 15) and BSCSCT (Figure 17) values show almost no resolution of workload levels over the six combined tasks.

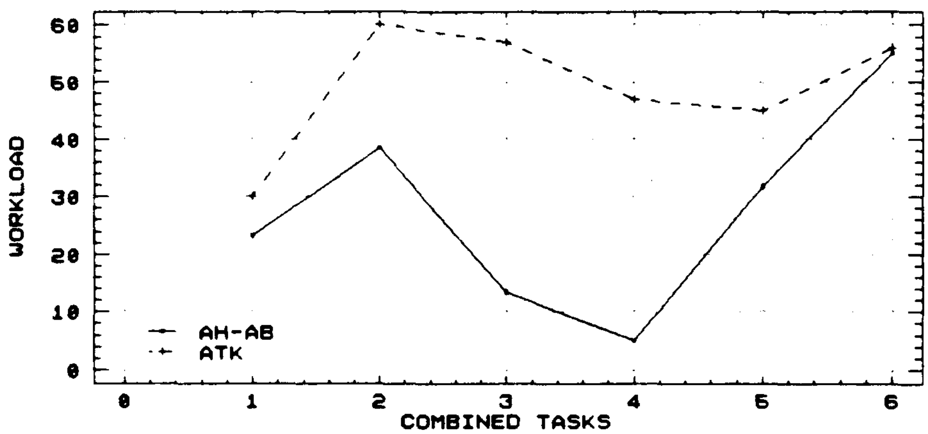

Figure 14. Attack Helicopter Model (ATK) and Survey (AH-AB) Workload Values

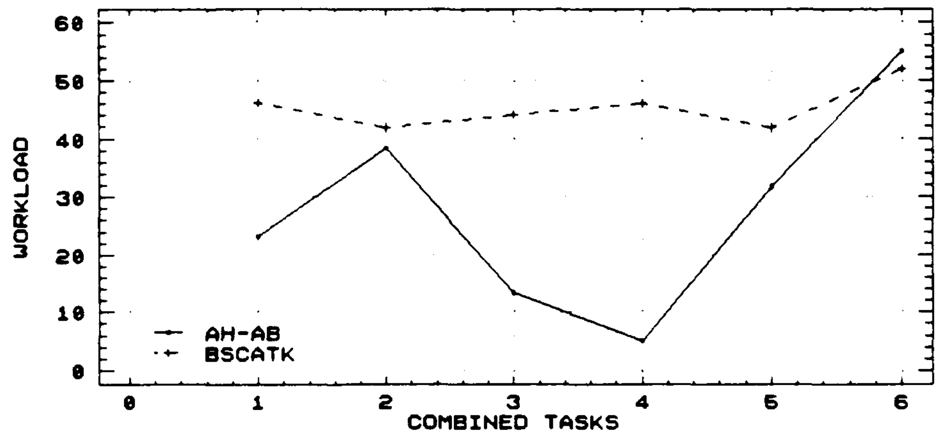

Figure 15. Attack Helicopter Model (BSCATK) and Survey (AH-AB) Workload Values

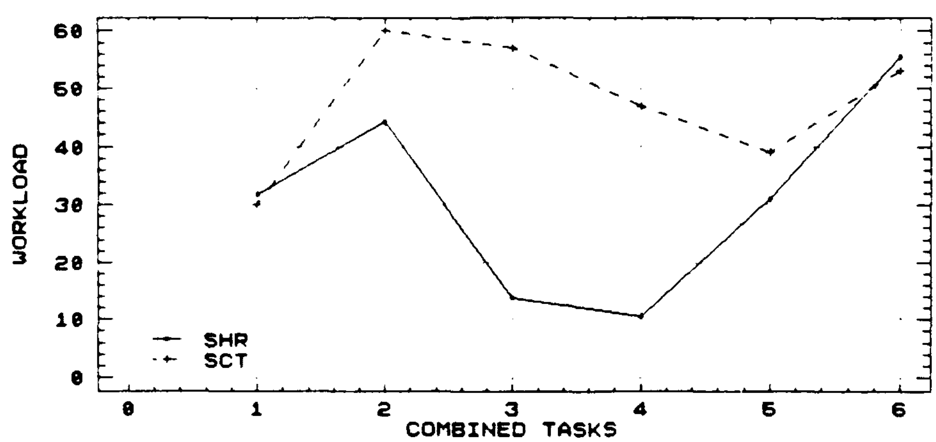

Figure 16. Scout Helicopter Model (SCT) and Survey (SHR) Workload Values

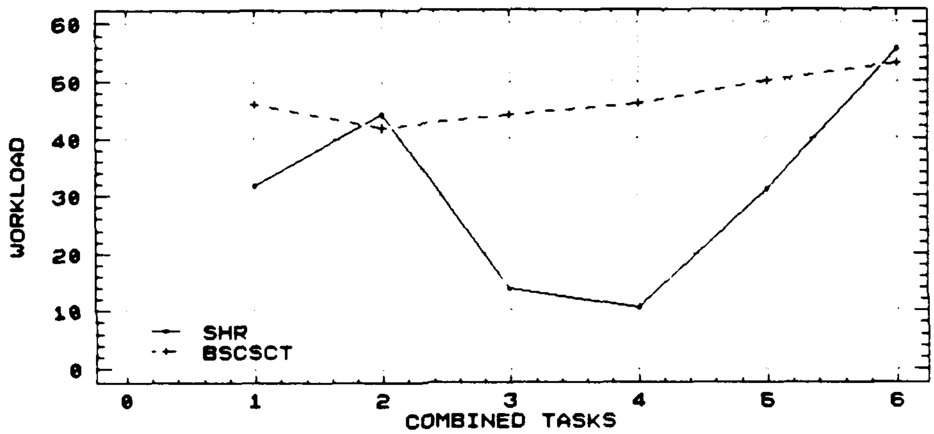

Figure 17. Scout Helicopter Model (BSCSCT) and Survey (SHR) Workload Values

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The purpose of this study was to determine the validity of the A^3I TLM as a device to measure the workload levels experienced by Army helicopter pilots. Empirically-derived workload data was collected from Army pilots, analyzed, and correlated with workload measurements generated by the TLM. Analysis of the empirical data provided insights into pilot-generated workload levels and provided a statistically acceptable basis upon which to judge the accuracy of TLM outputs. Furthermore, insights into the opinions of Army helicopter pilots concerning workload provides direction for future refinement of the TLM.

1. TLM Validity

In its present configuration, output from the TLM does not consistently yield measurements of Army helicopter pilot workload that correlate with pilot opinions of their workload levels, for the set of tasks tested. Of the two TLM techniques of evaluating workload, the second technique should be abandoned. This technique adds task-generated workload onto constant workload resulting from a basic underlying flying task (BSCATK and BSCSCT). This technique showed little workload level resolution and overestimated workload values for almost every task.

However, the first technique utilized by the TLM appears to provide better results. This technique analyzes aviator tasks separately from the actions associated with hands-on flying. Graphic analysis showed workload trends that in part agreed with the empirical measurements of workload. However, it should be noted that agreement between the model and the survey data was greater for the individual task measurements than for those related to the combined tasks.

2. Army Helicopter Pilot Workload Perceptions

Outputs from the TLM currently indicate that workload levels for the scout and attack helicopter pilots are almost identical. For essentially the same set of tasks embedded in realistic scout and attack helicopter scenarios, the data collected via the pilot surveys indicates that aviator workload varies according to the type aircraft flown and the type of mission conducted by the pilots. It is obvious that there are major discrepancies between the two methods for determining workload.

Results of the Friedman test indicate that survey responses from the Attack Helicopter Battalion participants cannot be pooled with those from the Cavalry Squadron. This is a strong indication that workload levels are not experienced the same by all of the aviators tested. The Spearman and Wilcoxon tests showed that, even among the scout pilots, workload is perceived differently by those scouts in the Cavalry Squadron than by those in the Attack Helicopter Battalion. These results provide strong evidence that the TLM may need modification to adjust workload according to the aviator's aircraft and specific mission.

B. RECOMMENDATIONS

Analysis of the degree of correlation between the TLM's workload output and the empirically-generated workload values obtained via the survey results in three recommendations. First, the TLM in its present configuration should not be used as the workload measuring mechanism in the MIDAS program. The TLM generally overestimates workload and provides an overly-narrow range of values for workload experienced by pilots performing a variety of tasks.

Second, the TLM shows promising potential in the measuring of workload associated with individual helicopter pilot tasks. This aspect of the TLM should be enhanced to take maximum advantage of this capability. Initial enhancements should address the mission and aircraft involved in generating pilot workload. Although the survey data indicates that these factors are significant, the TLM generates generic workload measurements independent of them.

Third, empirical workload data collected as described in this thesis should be used for future evaluations of the TLM. As the TLM matures, efforts should be made to ensure that output correlates highly with workload data obtained directly from Army pilots, as described in this study. However, the limited range of the survey data reported here should not serve as the only means of validating the TLM. TLM output should also be compared to other empirically-derived workload measurements, and to the output of other models designed to measure pilot workload.

C. SUGGESTIONS FOR FURTHER RESEARCH

Several aspects of this study deserve further investigation. First, helicopter pilot workload data should be obtained from another, independent source. This data then could be compared with the empirically-derived data collected in this study, to insure data validity. This same independent workload data also could be compared to the TLM's output. Second, the survey results reported here may be based on factors not investigated in this study, such as individual pilot experience. A more detailed analysis of the individual pilot responses may be warranted. Third, expanded surveys similar to those used for this study should be conducted in the future to broaden and refine the workload data base.

APPENDIX A. SCOUT HELICOPTER WORKLOAD SURVEY

SURVEY ON HELICOPTER PILOTING WORKLOAD

Thank you for your participation in this survey. Your assistance helps a NASA-Army team develop a human factors design tool aimed at improving the layout of future Army helicopter cockpits.

There are no right or wrong answers to the questions in this survey. The intent is to determine relative workload that you experience when flying. Your responses will help us determine what tasks you feel are harder or easier than others for the given scenario. Please answer the questions candidly.

The survey is anonymous. The combined data from all of the surveys will produce an overall "pilot" profile of task ratings.

The ratings and comparisons in the survey are listed randomly. No two surveys are exactly alike.

If you have any questions, hold up your hand and the survey administrating officer will assist you.

PAGE 1 OF 12

HOW TO FILL OUT THE SURVEY

Evaluate the following maneuvers as an individual crewman in the context of the given scenario and helicopter terrain flight in general. Difficulty is defined as a relative measure of combined physical and mental effort.

Evaluations are done in two parts. First, rate each maneuver by circling a value along the degree-of-difficulty continuum to indicate its difficulty.

Example 1:

MANEUVER	DEGREE OF DIFFICULTY
	low high
Fly straight and level	0__1__2__3__4__5__6__7__8__9__10
Autorotate at night	0__1__2__3__4__5__6__7__8__9__10

For the second part of the survey, individual maneuvers are compared with each other.

Choose the more difficult of the two by filling in the circle next to it.

Example 2:

Fly straight and level	O	O	Autorotate at night

SCOUT HELICOPTER SCENARIO

SETTING: You are the pilot of an OH-58 conducting a route reconnaissance in an unfamiliar hilly/wooded area. You are in the terrain flight mode along one side of the route, clearing the area while observing the route as frequently as possible. Due to pilot shortages, you are accompanied by a crewchief sitting in the left seat. He is familiar with the cockpit. He can hold a 1:50,000 map for you to observe. However, he cannot fly and you must double check his map reading activities. You are flying during the day with clear and calm weather conditions. An attack helicopter is overwatching you. However, you will not communicate with him during this mission segment. Enemy contact is possible.

Rate the difficulty of each maneuver by circling a value along the degree of difficulty continuum.

MANEUVER	DEGREE OF DIFFICULTY low — high
Follow another scout	0__1__2__3__4__5__6__7__8__9__10
NOE deceleration	0__1__2__3__4__5__6__7__8__9__10
Check torque meter and announce reading	0__1__2__3__4__5__6__7__8__9__10
Hover	0__1__2__3__4__5__6__7__8__9__10
Tell crewchief "Unmasking"	0__1__2__3__4__5__6__7__8__9__10
Unmask aircraft	0__1__2__3__4__5__6__7__8__9__10
Listen to crewchief describe what he sees	0__1__2__3__4__5__6__7__8__9__10
Turn up volume on ICS control panel	0__1__2__3__4__5__6__7__8__9__10
Determine present location (6 digit grid) as crewchief holds map	0__1__2__3__4__5__6__7__8__9__10

SURVEY # OHITR 1

Rate the difficulty of each maneuver by circling a value along the degree of difficulty continuum.

MANEUVER	DEGREE OF DIFFICULTY (low — high)
NOE deceleration behind another scout	0__1__2__3__4__5__6__7__8__9__10
Check torque meter and announce reading while NOE decelerating	0__1__2__3__4__5__6__7__8__9__10
Check torque meter and announce reading while hovering	0__1__2__3__4__5__6__7__8__9__10
Tell crewchief "Unmasking" while unmasking aircraft	0__1__2__3__4__5__6__7__8__9__10
Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover	0__1__2__3__4__5__6__7__8__9__10
Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees	0__1__2__3__4__5__6__7__8__9__10

Compare the two maneuvers on the same line. Choose the more difficult of the two by filling in the circle next to it.

MANEUVER 1	MANEUVER 2
Follow another scout O	O NOE deceleration
Follow another scout O	O Check torque meter and announce reading
Follow another scout O	O Hover
Follow another scout O	O Tell crewchief "Unmasking"
Follow another scout O	O Unmask aircraft
Follow another scout O	O Listen to crewchief describe what he sees
Follow another scout O	O Turn up volume on ICS control panel
Follow another scout O	O Determine present location (6 digit grid) as crewchief holds map
NOE deceleration O	O Check torque meter and announce reading
NOE deceleration O	O Hover
NOE deceleration O	O Tell crewchief "Unmasking"
NOE deceleration O	O Unmask aircraft

MANEUVER 1	MANEUVER 2
NOE deceleration O	O Listen to crewchief describe what he sees
NOE deceleration O	O Turn up volume on ICS control panel
NOE deceleration O	O Determine present location (6 digit grid) as crewchief holds map
Check torque meter and announce reading O	O Hover
Check torque meter and announce reading O	O Tell crewchief "Unmasking"
Check torque meter and announce reading O	O Unmask aircraft
Check torque meter and announce reading O	O Listen to crewchief describe what he sees
Check torque meter and announce reading O	O Turn up volume on ICS control panel
Check torque meter and announce reading O	O Determine present location (6 digit grid) as crewchief holds map
Hover O	O Tell crewchief "Unmasking"
Hover O	O Unmask aircraft

MANEUVER 1			MANEUVER 2
Hover	O	O	Listen to crewchief describe what he sees
Hover	O	O	Turn up volume on ICS control panel
Hover	O	O	Determine present location (6 digit grid) as crewchief holds map
Tell crewchief "Unmasking"	O	O	Unmask aircraft
Tell crewchief "Unmasking"	O	O	Listen to crewchief describe what he sees
Tell crewchief "Unmasking"	O	O	Turn up volume on ICS control panel
Tell crewchief "Unmasking"	O	O	Determine present location (6 digit grid) as crewchief holds map
Unmask aircraft	O	O	Listen to crewchief describe what he sees
Unmask aircraft	O	O	Turn up volume on ICS control panel
Unmask aircraft	O	O	Determine present location (6 digit grid) as crewchief holds map
Listen to crewchief describe what he sees	O	O	Turn up volume on ICS control panel

MANEUVER 1			MANEUVER 2
Listen to crewchief describe what he sees	O	O	Determine present location (6 digit grid) as crewchief holds map
Turn up volume on ICS control panel	O	O	Determine present location (6 digit grid) as crewchief holds map

Compare the two maneuvers on the same line. Choose the more difficult of the two by filling in the circle next to it.

MANEUVER 1			MANEUVER 2
NOE deceleration behind another scout	O	O	Check torque meter and announce reading while NOE decelerating
NOE deceleration behind another scout	O	O	Check torque meter and announce reading while hovering
NOE deceleration behind another scout	O	O	Tell crewchief "Unmasking" while unmasking aircraft
NOE deceleration behind another scout	O	O	Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover
NOE deceleration behind another scout	O	O	Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees
Check torque meter and announce reading while NOE decelerating	O	O	Check torque meter and announce reading while hovering
Check torque meter and announce reading while NOE decelerating	O	O	Tell crewchief "Unmasking" while unmasking aircraft
Check torque meter and announce reading while NOE decelerating	O	O	Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover

MANEUVER 1		MANEUVER 2
Check torque meter and announce reading while NOE decelerating	O O	Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees
Check torque meter and announce reading while hovering	O O	Tell crewchief "Unmasking" while unmasking aircraft
Check torque meter and announce reading while hovering	O O	Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover
Check torque meter and announce reading while hovering	O O	Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees
Tell crewchief "Unmasking" while unmasking aircraft	O O	Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover
Tell crewchief "Unmasking" while unmasking aircraft	O O	Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees
Listen to crewchief describe what he sees while you turn up volume on ICS control panel and hover	O O	Determine present location (6 digit grid) as crewchief holds map and you listen to him describe what he sees

PILOT BACKGROUND INFORMATION

Please answer the following questions regarding your aviation experience and qualifications.

1. Approximately how many flight hours do you have in the following aircraft as either a PC or PI? (Leave blank if little or no experience)

OH-58A/C	__________	AH-1	__________
OH-58D	__________	AH-64	__________
UH-1	__________	other rotary wing	_____
UH-60	__________	fixed wing	_________

2. Answer the following by indicating the approximate number of <u>flight hours</u>.

   a) Your total flight time: __________

   b) Flight time as an Instructor Pilot: __________

   c) Combat flight time: __________

   d) Flight time while qualified as a PC: __________

3. Answer the following by indicating the approximate number of <u>years</u>.

   a) Years as a PC: __________

   b) Years as an Army Aviator: __________

END OF SURVEY

THANK YOU FOR YOUR TIME AND EFFORT

APPENDIX B. ATTACK HELICOPTER WORKLOAD SURVEY

SURVEY ON HELICOPTER PILOTING WORKLOAD

Thank you for your participation in this survey. Your assistance helps a NASA-Army team develop a human factors design tool aimed at improving the layout of future Army helicopter cockpits.

There are no right or wrong answers to the questions in this survey. The intent is to determine relative workload that you experience when flying. Your responses will help us determine what tasks you feel are harder or easier than others for the given scenario. Please answer the questions candidly.

The survey is anonymous. The combined data from all of the surveys will produce an overall "pilot" profile of task ratings.

The ratings and comparisons in the survey are listed randomly. No two surveys are exactly alike.

If you have any questions, hold up your hand and the survey administrating officer will assist you.

PAGE 1 OF 12

HOW TO FILL OUT THE SURVEY

Evaluate the following maneuvers as an individual crewman in the context of the given scenario and helicopter terrain flight in general. Difficulty is defined as a relative measure of combined physical and mental effort.

Evaluations are done in two parts. First, rate each maneuver by circling a value along the degree-of-difficulty continuum to indicate its difficulty.

Example 1:

MANEUVER	DEGREE OF DIFFICULTY
	low — high
Fly straight and level	0__1__2__3__4__5__6__7__8__9__10
Autorotate at night	0__1__2__3__4__5__6__7__8__9__10

For the second part of the survey, individual maneuvers are compared with each other.

Choose the more difficult of the two by filling in the circle next to it.

Example 2:

Fly straight and level	O	O	Autorotate at night

ATTACK HELICOPTER SCENARIO

SETTING: You are the pilot of an armed AH-1 flying in the terrain flight mode. You are conducting travelling overwatch by following an aeroscout through an unfamiliar hilly/wooded area to a battle position. You will receive a target handoff from the firing position. Your crewmember will prepare for a TOW missile engagement and will not fly the aircraft during this mission segment. You are flying during the day with clear and calm weather conditions. Enemy contact is possible.

Rate the difficulty of each maneuver by circling a value along the degree of difficulty continuum.

MANEUVER	DEGREE OF DIFFICULTY (low — high)
Followscout	0__1__2__3__4__5__6__7__8__9__10
NOEdeceleration	0__1__2__3__4__5__6__7__8__9__10
Check torque meter and announce reading	0__1__2__3__4__5__6__7__8__9__10
Hover	0__1__2__3__4__5__6__7__8__9__10
Tell crewmember "Unmasking"	0__1__2__3__4__5__6__7__8__9__10
Unmaskaircraft	0__1__2__3__4__5__6__7__8__9__10
Listen to radio transmission from scout (direction to fire, range, target)	0__1__2__3__4__5__6__7__8__9__10
Switch master arm to "arm"	0__1__2__3__4__5__6__7__8__9__10
Interpret gunners position of TSU based on PSI information	0__1__2__3__4__5__6__7__8__9__10

Rate the difficulty of each maneuver by circling a value along the degree of difficulty continuum.

MANEUVER	DEGREE OF DIFFICULTY (low — high)
NOE deceleration behind scout	0__1__2__3__4__5__6__7__8__9__10
Check torque meter and announce reading while NOE decelerating	0__1__2__3__4__5__6__7__8__9__10
Check torque meter and announce reading while hovering	0__1__2__3__4__5__6__7__8__9__10
Tell crewmember "Unmasking" while unmasking aircraft	0__1__2__3__4__5__6__7__8__9__10
Listen to radio transmission from scout (direction to fire, range, target) while *switching master arm to "arm"*	0__1__2__3__4__5__6__7__8__9__10
Interpret gunners position of TSU, based on PSI information, while receiving target handoff from scout	0__1__2__3__4__5__6__7__8__9__10

Compare the two maneuvers on the same line. Choose the more difficult of the two by filling in the circle next to it.

MANEUVER 1		MANEUVER 2
Follow scout O		O NOE deceleration
Follow scout O		O Check torque meter and announce reading
Follow scout O		O Hover
Follow scout O		O Tell crewmember "Unmasking"
Follow scout O		O Unmask aircraft
Follow scout O		O Listen to radio transmission from scout (target, range, direction)
Follow scout O		O Switch master arm to "arm"
Follow scout O		O Interpret gunners position of TSU based on PSI information
NOE deceleration O		O Check torque meter and announce reading
NOE deceleration O		O Hover
NOE deceleration O		O Tell crewmember "Unmasking"

MANEUVER 1			MANEUVER 2
NOE deceleration	O	O	Unmask aircraft
NOE deceleration	O	O	Listen to radio transmission from scout (target, range, direction)
NOE deceleration	O	O	Switch master arm to "arm"
NOE deceleration	O	O	Interpret gunners position of TSU based on PSI information
Check torque meter and announce reading	O	O	Hover
Check torque meter and announce reading	O	O	Tell crewmember "Unmasking"
Check torque meter and announce reading	O	O	Unmask aircraft
Check torque meter and announce reading	O	O	Listen to radio transmission from scout (target, range, direction)
Check torque meter and announce reading	O	O	Switch master arm to "arm"
Check torque meter and announce reading	O	O	Interpret gunners position of TSU based on PSI information
Hover	O	O	Tell crewmember "Unmasking"

MANEUVER 1			MANEUVER 2
Hover	O	O	Unmask aircraft
Hover	O	O	Listen to radio transmission from scout (target, range, direction)
Hover	O	O	Switch master arm to "arm"
Hover	O	O	Interpret gunners position of TSU based on PSI information
Tell crewmember "Unmasking"	O	O	Unmask aircraft
Tell crewmember "Unmasking"	O	O	Listen to radio transmission from scout (target, range, direction)
Tell crewmember "Unmasking"	O	O	Switch master arm to "arm"
Tell crewmember "Unmasking"	O	O	Interpret gunners position of TSU based on PSI information
Unmask aircraft	O	O	Listen to radio transmission from scout (target, range, direction)
Unmask aircraft	O	O	Switch master arm to "arm"
Unmask aircraft	O	O	Interpret gunners position of TSU based on PSI information
Listen to radio transmission from scout (target, range, direction)	O	O	Switch master arm to "arm"

MANEUVER 1		MANEUVER 2
Listen to radio transmission from scout (target, range, direction)	O O	Interpret gunners position of TSU based on PSI information
Switch master arm to "arm"	O O	Interpret gunners position of TSU based on PSI information

Compare the two maneuvers on the same line. Choose the more difficult of the two by filling in the circle next to it.

MANEUVER 1	MANEUVER 2
NOE deceleration behind scout O	O Check torque meter and announce reading while NOE decelerating
NOE deceleration behind scout O	O Check torque meter and announce reading while hovering
NOE deceleration behind scout O	O Tell crewmember "Unmasking" while unmasking aircraft
NOE deceleration behind scout O	O Listen to radio xsmn from scout (direction, range, target) while switching master arm to "arm"
NOE deceleration behind scout O	O Interpret gunners position of TSU based on PSI info, while receiving target handoff from scout
Check torque meter and announce reading while NOE decelerating O	O Check torque meter and announce reading while hovering
Check torque meter and announce reading while NOE decelerating O	O Tell crewmember "Unmasking" while unmasking aircraft
Check torque meter and announce reading while NOE decelerating O	O Listen to radio xsmn from scout (direction, range, target) while switching master arm to "arm"
Check torque meter and announce reading while NOE decelerating O	O Interpret gunners position of TSU based on PSI info, while receiving target handoff from scout

MANEUVER 1			MANEUVER 2
Check torque meter and announce reading while hovering	O	O	Tell crewmember "Unmasking" while unmasking aircraft
Check torque meter and announce reading while hovering	O	O	Listen to radio xsmn from scout (direction, range, target) while switching master arm to "arm"
Check torque meter and announce reading while hovering	O	O	Interpret gunners position of TSU based on PSI info, while receiving target handoff from scout
Tell crewmember "Unmasking" while unmasking aircraft	O	O	Listen to radio xsmn from scout (direction, range, target) while switching master arm to "arm"
Tell crewmember "Unmasking" while unmasking aircraft	O	O	Interpret gunners position of TSU based on PSI info, while receiving target handoff from scout
Listen to radio xsmn from scout (direction, range, target) while switching master arm to "arm"	O	O	Interpret gunners position of TSU based on PSI info, while receiving target handoff from scout

PILOT BACKGROUND INFORMATION

Please answer the following questions regarding your aviation experience and qualifications.

1. Approximately how many flight hours do you have in the following aircraft as either a PC or PI? (Leave blank if little or no experience)

OH-58A/C	________	AH-1	________
OH-58D	________	AH-64	________
UH-1	________	other rotary wing	_____
UH-60	________	fixed wing	________

2. Answer the following by indicating the approximate number of flight hours.

   a) Your total flight time: ________

   b) Flight time as an Instructor Pilot: ________

   c) Combat flight time: ________

   d) Flight time while qualified as a PC: ________

3. Answer the following by indicating the approximate number of years.

   a) Years as a PC: ________

   b) Years as an Army Aviator: ________

END OF SURVEY

THANK YOU FOR YOUR TIME AND EFFORT

APPENDIX C. SPEARMAN RANK CORRELATION SIGNIFICANCE LEVELS

INDIVIDUAL-TASK PAIRED COMPARISONS						
	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
AH-AB	-	**0.006**	-	-	-	-
AH-CV		-	-	-	-	-
SH-AB			-	**0.011**	**0.009**	-
SH-CV				-	-	**0.048**
EO-AB					-	**0.013**
EO-CV						-

INDIVIDUAL-TASK RATINGS						
	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
AH-AB	-	**0.018**	-	-	-	-
AH-CV		-	-	-	-	-
SH-AB			-	0.079	0.069	-
SH-CV				-	-	**0.027**
EO-AB					-	**0.011**
EO-CV						-

COMBINED-TASK PAIRED COMPARISONS						
	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
AH-AB	-	0.110	-	-	-	-
AH-CV		-	-	-	-	-
SH-AB			-	**0.000**	**0.000**	-
SH-CV				-	-	0.060
EO-AB					-	0.060
EO-CV						-

COMBINED-TASK RATINGS						
	AH-AB	AH-CV	SH-AB	SH-CV	EO-AB	EO-CV
AH-AB	-	0.136	-	-	-	-
AH-CV		-	-	-	-	-
SH-AB			-	**0.035**	**0.035**	-
SH-CV				-	-	**0.035**
EO-AB					-	**0.035**
EO-CV						-

LIST OF REFERENCES

Army-NASA Aircrew Aircraft Integration Program, *Executive Summary*, NASA Ames Research Center, 1990.

Chambers, J. M., and others, *Graphical Methods for Data Analysis*, pp. 82-86, Wadsworth & Brooks, 1983.

Dunn-Rankin, P., *Scaling Methods*, pp. 79-82, Lawrence Erlbaum Associates, 1983.

Hamburg, M., *Statistical Analysis for Decision Making*, pp. 576-578, Harcourt Brace Jovanovich, 1987.

Hart, S. G., and Staveland, L. E., *Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research*, NASA-Ames Research Center, 1988.

Kantowitz, B. H., and Casper, P. A., "Human Workload in Aviation," *Human Factors in Aviation*, Academic Press, 1988.

Mendenhall, W., Scheaffer, R. L., and Wackerly, D. D., *Mathematical Statistics with Applications*, 4th ed., PWS-Kent Publishing Co., 1990.

Rice, J. A., *Mathematical Statistics and Data Analysis*, pp.336-337, Wadsworth & Brooks, 1988.

Rosenthal, R., and Rosnow, R.L., *Essentials of Behavioral Research: Methods and Data Analysis*, pp. 81-139, McGraw-Hill Book Co., 1984.

Staveland, L., *Army-NASA Aircrew/Aircraft Integration Program Task Loading Model Software Documentation*, NASA-Ames Research Center, 1990.

Thurstone, L. L., *The Measurement of Values*, pp. 67-81, The University of Chicago Press, 1963.

United States Army Research Institute for the Behavioral and Social Sciences TR 851, *Operator Workload: Comprehensive Review and Evaluation of Operator Workload Methodologies*, by R. J. Lysaght and others, pp. 81-99, June 1989.

Zatkin, J. L., *Scaling by Magnitude Estimation*, Naval Postgraduate School, pp. 1-6, 1983.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, VA 22304-6145	2
2.	Library, Code 52 Naval Postgraduate School Monterey, CA 93943-5002	2
3.	NASA-Ames Research Center ATTN: Jim Hartzell MS262-1 Moffett Field, CA 94035-1000	4
4.	Professor Judith Lind Code OR/Li Naval Postgraduate School Monterey, CA 93943-5000	2
5.	CDR Thomas Mitchell Code 602 Naval Air Development Center Warminster, PA 18974-5000	2
6.	CPT James Galvin 4 Wren Way Court Stafford, VA 22554	2
7.	Joseph Kern Code 6022 Naval Air Development Center Warminster, PA 18974	1