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INTERPRETED COOPER-HARPER FOR BROADER USE

David L. Green
President, Starmark Corporation
Arlington, Virginia

Hal Andrews (retired)
Technical Director, Research and Technology
Naval Air Systems Command

Donald W. Gallagher
Night Vision Operations Project Manager
FAA Technical Center, Atlantic City International Airport, New Jersey

ABSTRACT

The current aircraft assessment process typically makes extensive use of operational personnel during simulations and operational evaluations, with increased emphasis on evaluating the many pilot and/or operator/aircraft control loops. The need for a crew assessment in this broader arena has produced a variety of rating scales. The Cooper-Harper Rating Scale is frequently misused and routinely overlooked in the process, for these applications often extend the scale's use beyond its originally intended application. This paper agrees with the broader application of the Cooper-Harper Rating Scale and presents a concept for the development of a "use unique" Interpreted Cooper-Harper Scale to help achieve this objective. This interpreted scale concept was conceived during efforts to support an FAA evaluation of a night vision enhancement system. It includes descriptive extensions, which are faithful to the intent of the current Cooper-Harper Scale and should provide the kind of detail that has historically been provided by trained test pilots in their explanatory comments.

NOMENCLATURE

CHPRS	Cooper-Harper Pilot Rating Scale
CM	Cockpit Management
DI	Deck Interface
EMS	Emergency Medical Service
FAA	Federal Aviation Administration
HQR	Handling Quality Rating
ICHRS	Interpreted Cooper-Harper Rating Scale
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IPR	Interpreted Pilot Rating
LFE	Limit Flight Envelope
MCHRS	Modified Cooper-Harper Rating Scale
NAS	National Airspace System
NFE	Normal Flight Envelope
NOE	Nap-of-the-Earth
OFE	Operational Flight Envelope
PR	Pilot Rating
VMC	Visual Meteorological Conditions

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INTRODUCTION

The Cooper-Harper Pilot Rating Scale (CHPRS) has been very effective in handling qualities research and development applications, serving as an evaluation tool and communications medium in a community of trained experimental and R&D test pilots and engineers. The success of CHPRS has in some measure been due to the discipline involved in its use. This discipline has been instilled thorough training at test pilot schools, use of the scale in the military acquisition process, and because of adherence to the asterisk note which appears on the scale: "Definition of required operation involves designation of flight phase and sub-phases with accompanying conditions".

In Reference 1, Harper and Cooper emphasize the need to follow this stricture. While recognizing the difficulties in doing so, they also recognize the adverse impact of failure to treat this instruction in a comprehensive way.

Currently, the assessment process in new product development for aircraft has taken on a greater operational flavor. This is found both at the project initiation stage, where extensive simulations using operational personnel are becoming the rule, and at the final approval stage where operational personnel hold the final stamp. At the same time, the greatly increased integrated complexity of the pilot machine interface systems increases the emphasis on evaluating the many in-flight dynamic components of the pilot and/or operator/aircraft control loop. This complexity is amplified for rotorcraft, where the total flight regime includes the widest variety of flight path tasks.

The need for a rating scale in this broader arena has required the use of evaluation scales of some sort, and perhaps because piloting considerations are generally involved --- but not always --- the Cooper-Harper scale is frequently used. Sometimes it is misused in this broader context. Sometimes it is not applied because of concern for misuse, or a bureaucratic constraint or because it is simply not understood.

To those who have been trained in the use of the scale, it is clear and provides a concise and useful way for members of the handling qualities community to communicate. To many outside the handling qualities community, a reluctance to apply the scale is evoked by a lack of confidence in the use of subjective pilot evaluations. This group typically desires to use a pass fail criteria pilot (crew) evaluation or alternately base decisions on quantitative measures alone. It appears that the reservations of some are reinforced by their unsuccessful attempts to use the scale. These attempts may have failed to observe the asterisked stricture of the CHPRS (see Figure 1).

A case can be made for using some other scale, or using the CHPRS with a second overlapping workload scale, or using no subjective scale at all. But because handling qualities are major components of all aircraft pilot/operator assessments, and because the scale has always included consideration of workload, it seems most appropriate to improve our understanding of the existing CHPRS and broaden its applications. To this end, this paper proposes that a well understood, expanded and interpreted version of the CHPRS would:

(1) Help the aviation community define the factors which respond to the asterisk note on the CHPRS, minimizing variance in pilot ratings.
(2) Include a concept which involves developing "application unique" extensions to the descriptive content of the scale to enhance its use by both trained engineering test pilots and by operational evaluation pilots. These expanded definitions will allow pilots to:
    (a) Select a correct rating which may be a whole number or a half pilot rating (PR), and
    (b) provide additional comments which will help others understand the experience underlying the selected rating (in terms which include flying qualities, flying workload, cockpit management (CM) workload and relevant performance measures).
(3) Better explain how experienced subject pilots can predict the suitability of an aircraft for operations in environments not specifically evaluated.

In summary, paper supports the broader application of the current CHPRS and it offers a concept for achieving this objective through the introduction of an use-specific, Interpreted Cooper-Harper Pilot Rating Scale.

COOPER-HARPER RATINGS

Background

The first widely used pilot rating scale was introduced in 1957 and known as the Cooper Scale (Reference 2). This was followed by an interim scale in 1966 (Reference 3) and finally in 1969 the Cooper-Harper rating scale, presented here as Figure 1, was published in NASA TN D-5153 (Reference 4).

The key to effective use of this scale lies in strict adherence to the guidelines contained in References 1 and 4, and in the thorough understanding of the scale's origins, strengths and limitations. In this regard, Harper and Cooper reported in Reference 1 that the "nearly universal use of the Cooper-Harper rating scale for handling qualities assessments is not commensurate with the general lack of access to and familiarity with NASA TN D-5153 (which gives background guidance, definition of terms, and recommended use)". In other words, everybody uses the scale, but few have studied Reference 4 and/or observe the counsel of Reference 4.

It is important to understand that most of the ideas and suggestions in this paper are not new. For the most part, they are over 30 years old and alluded to in the above references. This paper does provide suggested ways to implement the guidance of References 1 and 4 as well as expanding the application of the scale to address the current needs of the industry. In this regard, the following paragraphs quote, paraphrase, and amplify a number of key concepts and instructions contained in the primary references:

A Communication Enhancement Tool

There are two parts to the rating process: "The pilot's commentary on the observations he made, and the rating he assigned. ---- They are the most important data on the closed-loop pilot-airplane combination which the engineer has." (Reference 1). The rating numbers themselves are an aeronautical short hand developed for recording, quantifying and analyzing subjective data. These ratings are a means to an end. They are not the end of the process.

Engineering Test Pilots

The scale in Figure 1 was developed for use by experimental and engineering test pilots. These test pilots typically have an operational background and have been trained to communicate with the engineering community. The military pilot becomes a test pilot after acquiring a personal understanding of the environment, threat and related friendly weapons systems which will define the total combat environment. They then learn (civil or military) to evaluate flying qualities in context with the cockpit workload with a readiness to deal with the environment and the adversity introduced by equipment failures.

Pilot Comments

Engineering test pilots are expected to know how to provide task ratings and comments which are useful in the analysis of the flights they conduct. It is not enough to provide a rating. The pilot must provide comments as to what the pilot experienced. The pilot must report what did and (sometimes) what did not influence the assignment of a given rating. For example, one pilot may use one technique to compensate for a lateral directional oscillation and be very successful, while a second pilot may not understand the best compensatory technique, have a great deal more trouble and assign a poor rating.

Operational Pilots

There are three probable situations where the operational pilots (unschooled in the methods of the engineering test pilots) could be expected to utilize the CHPRS. --- In the ground based and inflight

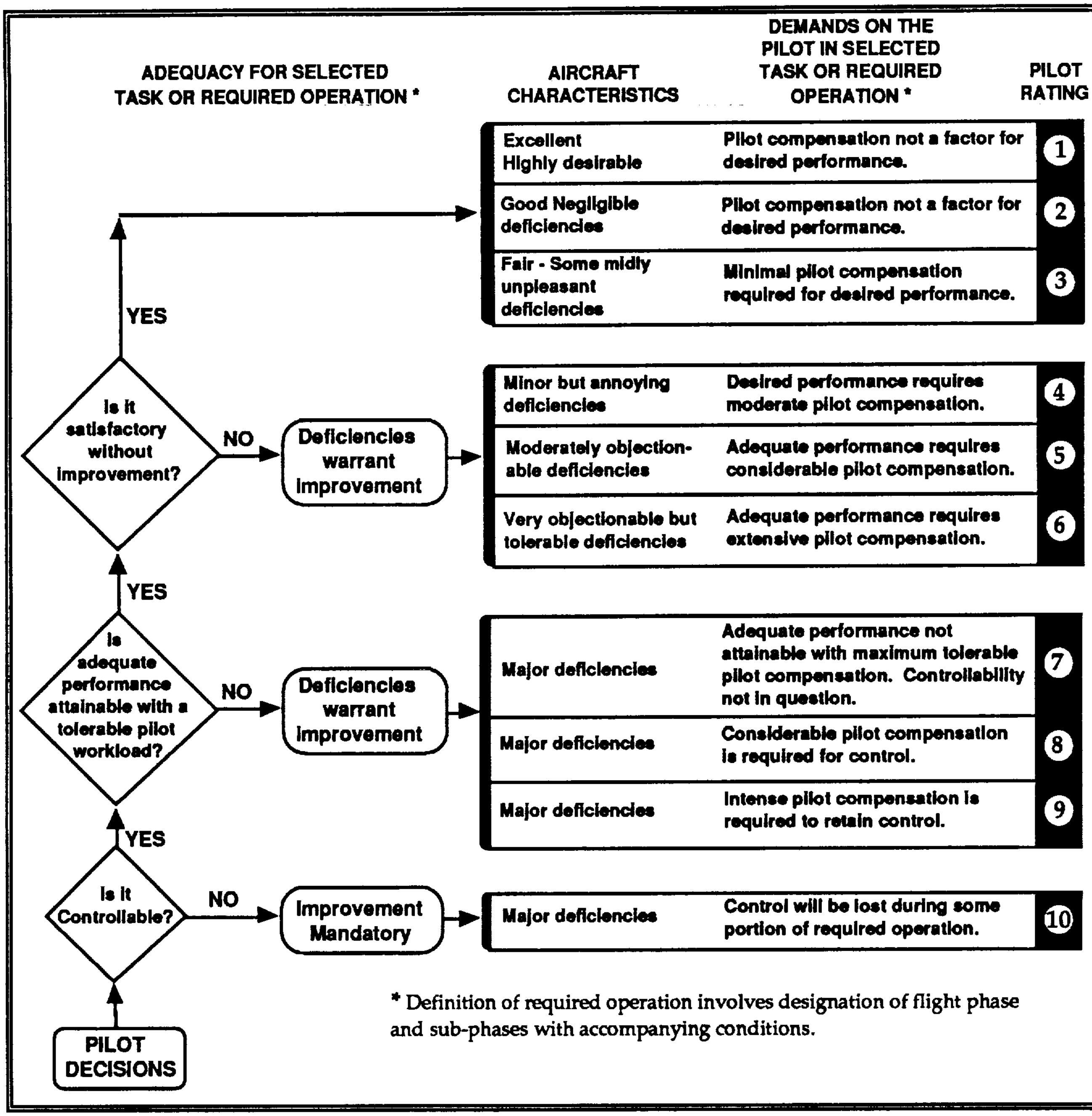


Figure 1: The Cooper-Harper Pilot Rating Scale

simulations cases, the resident simulation staff is very familiar with the use of the CHPRS and they are inclined to attempt to have the operational pilot use the CHPRS. The results of this application are potentially flawed because the operational pilots may not understand the proper use of the scale. --- The scale looks simple, and these otherwise very capable pilots understate their lack of comprehension in an effort to be accommodating.

In the operational evaluation venue, the resident engineers and analysts are much less familiar with the CHPRS and often hesitate to employ it. Here an opportunity for broader use is missed.

In brief, the CHPRS is not sufficiently user friendly for many operational pilot applications unless the pilots and engineers are diligently trained in its use.

The Scale

The scale presented in Figure 1 incorporates 10 ratings. Cooper and Harper feel that these ratings should be adequate for most evaluations (Reference 4). While they also recognize that the use of half rating gradation is appropriate for some applications (e.g. 3.5 and 4.5), they discourage the practice. One reason for this reluctance is obvious. There are no definitions of half ratings.

Another argument against the use of half ratings asserts that ability of pilots to discriminate between flying qualities (workload and performance) is not sufficient to empower them to assign half ratings. The data in Figure 2 argues against this last assertion, for it contains a family of boundaries which separate areas of the flight envelope which were judged by an engineering test pilot to contain flying qualities that differ by one half of one PR. Boundaries of this sort were first identified in Reference 5, and later defined in flight with a small, modern helicopter. Over 60 pilot ratings were recorded during stabilized, standard rate turning flight, while observing error limits of ± 5 knots and ± 50 ft/min. The actual ratings assigned to each area of the flight envelope vary as a function of the accompanying conditions (e.g., turbulence, lighting, visibility, etc.).

Pilot Compensation/Workload Factors

The level of pilot compensation necessary to achieve "adequate" or "desired" performance (see Figure 1) is integral to the use of CHPRS. Implicitly, this compensation is directly translatable to workload. Furthermore, the phrase "definition of required operation" (included in the asterisk note of the CHPRS) serves to include both direct flight control and other flight management functions which the pilot must perform to achieve satisfactory task performance.

In the real world, the pilot approaches a flight task with the expectation that the task is doable. That is, pilots look at all of the sources of workload and attempt to cope with each source in the way which produces the best performance with a minimum of effort. As Harper and Cooper observe in Reference 1, "the pilot adapts". From the view of the systems engineer, the pilot learns how to achieve the desired performance while optimally distributing the piloting (handling qualities) workload and cockpit management (CM) workload. In military combat aircraft, mission equipment monitoring and task execution workload is also involved.

The engineer understands that tasks are distributed by the crew in a natural attempt to avoid spikes in workload which are likely to be accompanied by an unwanted dip in performance. It is this effective search for adaptive techniques which exemplifies the pilot's contribution to crew-machine performance.

As the total workload builds, the pilot may have reason to periodically (albeit very briefly) allocate a high priority to CM tasks and allow errors in the flight path to build during a period of deferred attention. The performance during such unattended periods is therefore judged differently. The pilot who is prepared to allow an aircraft to drift off speed, or roll away from level flight, has substituted new (temporary) limits on

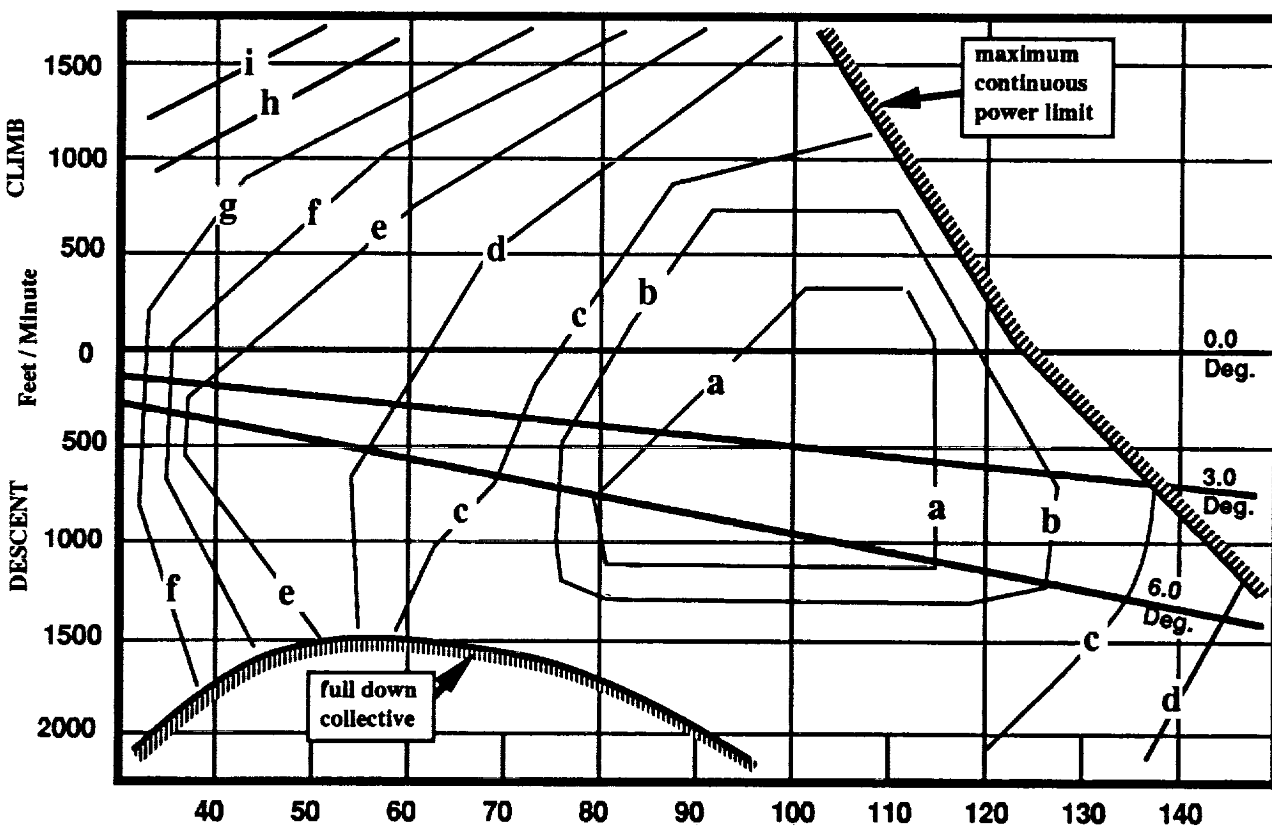


Figure 2: Boundaries of Flying Qualities Which Represent A Change of 0.5 Pilot Rating

the allowable flight path errors. These larger allowable errors apply only during the performance of the priority CM task. Typically, the pilot monitors the aircraft's departure from trim, and if every thing goes well, the CM task is completed during one period of unattended flight. If the aircraft departs too quickly, or is difficult to return to trim, several periods of unattended or deferred flight control activity may be utilized to complete the CM task. Pilots evaluate such shared attention requirements and make a determination as to suitability.

Pilots also develop CM techniques which minimize the time required to accomplish CM tasks. For example, they learn how to identify switches by location, shape and mode of operation. This allows them to find a switch while focusing their eyes on a flight control task. The mind is obviously able to share its attention more rapidly than the eyes, especially when head movement is required.

In addition, pilots who are faced with the need to use the right hand to conduct a CM task may use the left hand to control pitch and roll during the CM event. A pilot may also use a knee to hold a collective in position, or use both feet on the directional controls to keep the aircraft level in roll. Such techniques may result in substantially less deviation from the desired flight path with little or no increase in total workload. This is the way pilots learn to get the job done in the real world. Test pilots know these techniques and engineers need to report which ones they use.

When pilots encounter a task which is not doable, many will attribute the failure to a personal inability. But, the more experienced the pilot, the less likely this will occur. Never-the-less, this is one more reason why it is very important for the analyst to understand the attitudes of subject pilots.

In the vein of doable tasking, the "unexpected" typically places the ultimate stress on crew performance. The occurrence of unplanned events such as equipment malfunctions, unexpected route changes and unforecast weather are all a part of the equation. A totally correct evaluation of these events typically requires a concomitant engineering analysis to determine the probability of a given event.

Defining The Task

The CHPRS (Figure 1) contains a note which is often given less than adequate consideration. The note refers to the "task" or "operation" and alerts us to the effect: "Definition of required operation involves designation of flight phases and sub-phases with accompanying conditions."

Flight Phases and Sub-Phases. If we translate the definitions of flight phase and sub phases as stated in Reference 4, we find that hovering flight and cruise flight are two typical flight phases. Activities associated with achieving a 40 ft hover is a sub phase. Maintaining a steady 40 ft hover is also a sub phase.

Accompanying Conditions. The factors which collectively define "accompanying conditions" substantially influence the assignment and analysis of pilot ratings. Typically, the project engineer must define accompanying conditions prior to the flight for they at least partially define the test objective or "scope of test". The pilot needs this guidance to accomplish the desired evaluation. The actual accompanying conditions, observed during the execution phase, must be recorded to support the best possible analysis and avoid unexplainable variance in the data.

The factors which define some rotorcraft tasks can normally be selected from a list like the partial one presented below:

(1) VMC or IMC task
- type of cue field and display augmentation
- display system

(2) Performance Objectives
- altitude (absolute or as measured by radar altimeter)
- horizontal position error (X and Y)
- heading variation limits
- main transmission torque limits
- engine operating limits
- attitude variation limits during corrections ($\pm$ degrees)
- attitude variation allowed as the result of a gust or turbulence
- time available to conduct non flight control cockpit tasks (schedule of shared time)

(3) Environmental Factors
- underlying surface
- near field visual screen
- far field visual screen
- near hazards-obstructions to hover
- lighting
- visual range
- obstructions to visibility
- precipitation
- smoke, fog. dust, snow, sun.
- glare, sun, moon, reflections

While most of the flying qualities community clearly understands the importance of the items listed under (1) and (2) above, the environmental factors under (3) seem to be less appreciated and are more often than not treated in too general a way. For example, limit environmental conditions are sometimes established by as few as one or two parameters (e.g., visibility). Such an abbreviated treatment is often inadequate, especially in the case of helicopters required to operate to and from a variety of fixed and moving platforms, in a rapidly changing air mass, day and night. Figure 3 was adapted from Reference 5 to expand on the list above and to illustrate the variety of conditions which may be of interest during rotorcraft evaluations. While this figure is admittedly incomplete, figures like this should be provided so that pilots and engineers can accurately define sets of conditions for evaluation. In the real world, we find that rotorcraft pilots are interested in a variety of environmental conditions, any or all of which can represent a limit condition.

Before leaving this subject, it is important to recognize that the introduction of "usable cue environments" in Reference 6 is an important contribution and a significant step in the right direction, as is the Navy's deck interface (DI) testing methodology which recognizes ship motion, lighting, wind, and other factors identified in Figure 3.

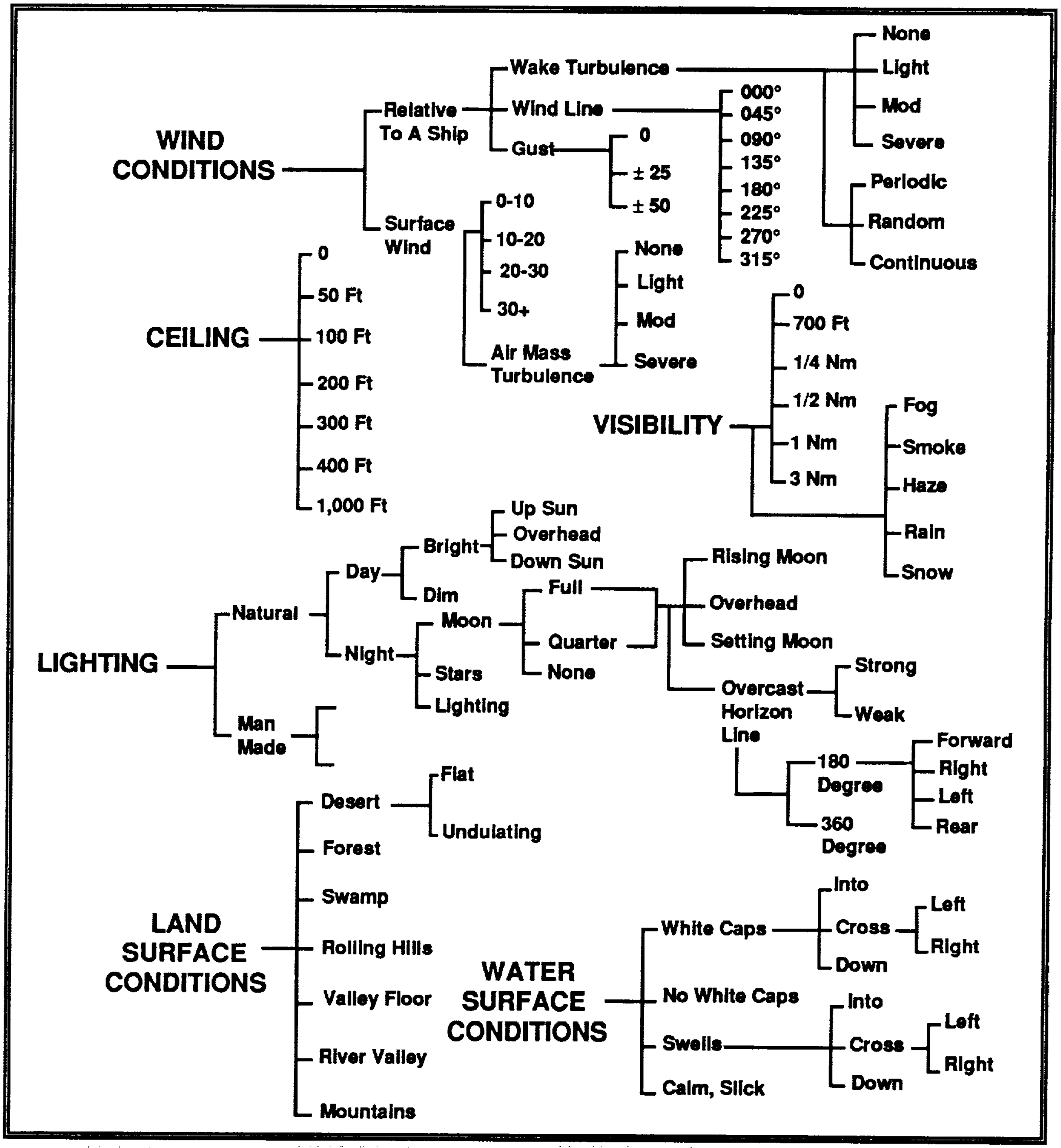


Figure 3: Characteristics Defining Operational Environment

FLIGHT CONDITION	ATMOSPHERIC DISTURBANCE								
	LIGHT			MODERATE			SEVERE		
	FLIGHT ENVELOPE								
	NFE	OFE	LFE	NFE	OFE	LFE	NFE	OFE	LFE
PROBABLE CONDITION	S	S	A	A	C	C	C	C	C
IMPROBABLE CONDITION	A	A	C	C	C		C		

S = SATISFACTORY   A = ADEQUATE   C = CONTROLLABLE

NFE: Normal Flight Envelope   OFE: Operational Flight Envelope   LFE: Limit Flight Envelope

Figure 4: Probability Guidelines and Minimum HQ Requirements

Probability of Encounter

The probability of encountering adverse environmental factors is another important consideration when evaluating the suitability of flying qualities and workload of a real aircraft. It would appear that the probability of encountering certain environments can be treated in a way that is similar to the treatment of failure modes as addressed in References 6, 7, 8 and 9.

In this regard, McElroy does an excellent job in Reference 10 of addressing and the probability of simultaneously encountering specific levels of atmospheric disturbance and failure states in context with flight envelopes. Figure 4 has been reproduced from Reference 10 as it is an excellent summary of the author's concept. In support of this figure, the author observes that the FAA could use subjective pilot ratings (from a scale like that in Figure 1) to determine compliance with the criteria "satisfactory," "adequate," and "controllable" (Figure 4), an idea which is still new to much of the FAA.

Analyzing Environmental Effects

Plotting pilot rating data as a function of one or more variables will often help the analyst develop the highest degree of confidence in the data. This concept is demonstrated in Reference 11 which presents a family of six data plots (one each for 5, 10, 15, 20, 25, 30 knots of wind), two of which are characterized in Figure 5. Observe that pilot ratings are plotted as a function of azimuth for two wind speeds.

Note that pilot ratings vary as a function of both wind speed and azimuth. Although not shown, the ratings can also vary as a function of gross weight, power available, center of gravity, rotor RPM, turbulence, visibility, lighting, and a host of other variables. If you inspect the 5 and 15 knot data for the wind azimuth of 300°, you will note that the pilot rating changes from a respectable PR 3 at 5 knots of wind to a relatively poor rating of PR 5 at 15 knots. But why? The pilots comments should provide the best insight. This is a clear demonstration of the need for pilot comments.

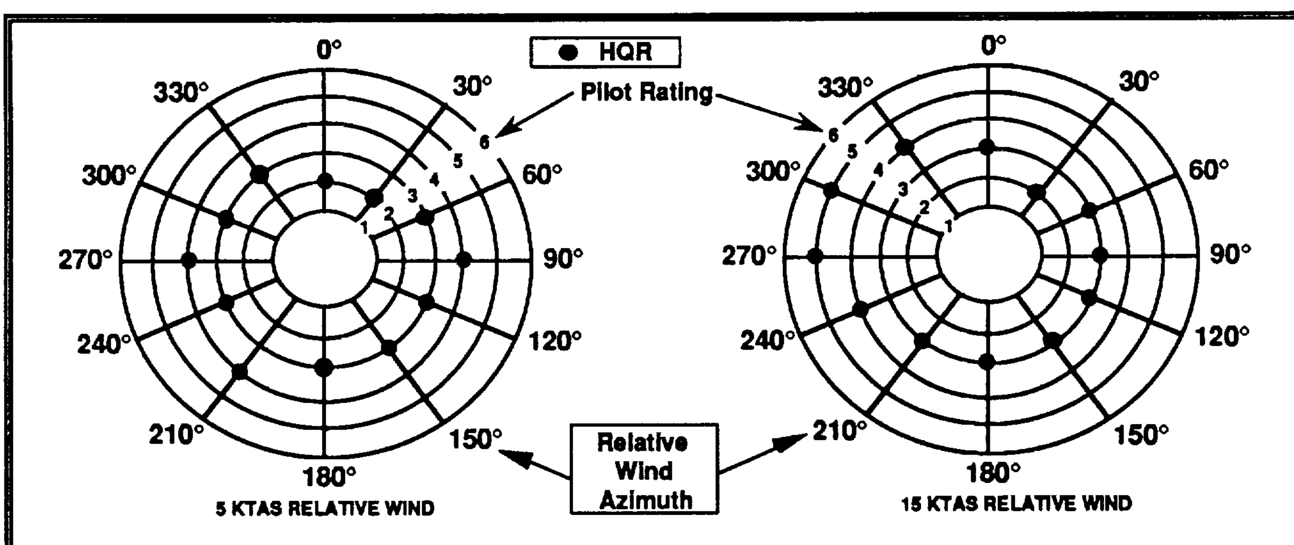


Figure 5: Handling Qualities For Various Wind Azimuth Angles (Pre-landing hover) Over Deck of Small Ships

Evaluating Simulation Facilities

Pilot ratings can also be used to evaluate the authenticity of a simulator. One way to check the authenticity of the simulation is to ask the crews to evaluate (or interpret) the simulator visual and motion systems while simulating an aircraft with which they are familiar.

To illustrate this application, the results of a hypothetical simulator evaluation are presented here as Figure 6. This figure contains the possible result of a day flight and a night flight in an existing helicopter followed by an attempt to replicate the real world test conditions in a ground based simulator. The data shown for "Bright Day - Actual Flight" in this figure is taken directly from Figure 5. In this illustration, the pilot's "actual flight" PRs and "simulated flight" PRs are approximately equal for the dark night case, but the data for the bright day case reveals a significant disagreement. The comments accompanying the pilot's ratings should confirm the ratings and provide insight into the probable cause. Depending upon the comparative evaluation of the pilot's control activity and overall performance, the findings would seem to suggest that the visual representation lacked adequate authenticity in the "bright day" case. In contrast, the dim, night scene was adequate. This is an important finding in and of itself.

The results of a second hypothetical evaluation are presented in Figure 7 which illustrates an alternative format for evaluating the authenticity of a simulator. In this case, the pilot first uses a real helicopter to conduct a demanding task in seven different, real world environments. The seven combinations have been plotted in ascending order for convenience.

When the same pilot attempts the identical task in the simulated environments (duplicated in the simulator), the pilot ratings should agree. If they do not agree, the pilots comments associated with each rating should provide useful data as to the cause of the difficulty. That is, an analyses of pilot control activity, attitude error, flight path error, etc., should include an equally exhaustive analysis of pilot comments.

Minimizing Variability In Ratings

Variance in PR data feeds the argument that the subjective rating approach can produce erroneous results. Cooper-Harper tell us to expect a limited amount of variability in ratings. Disparity in pilot background can produce variation in the pilot ratings. In addition, Cooper-Harper tell us that some pilots may be predisposed for or against a given configuration. In addition, some variability in PRs may simply reflect the presence of one or more factor(s) which were not accounted for in the definition of the experiment. That is, an important factor may not have been recorded.

Most of these sources of variability can be minimized through diligent planning. In particular, pilots and engineers are urged develop a table such as that included as Figure 3. Once the data are collected, presentations formats such as those suggested by Figures 5, 6 and 7 can help the analyst develop the best possible understanding of PR data and at the same time minimize the possibility of scatter in the data.

Extrapolations

The CHPRS authors recognize that some would have pilots evaluate only the situation experienced (first hand) by the subject pilot. Others would have pilots use a simulator evaluation experience to predict/-extrapolate to the real world. For example, assume that during a landing experiment, employing an inflight simulator, the pilot evaluates the test configuration only on a clear, bright sunny day. The pilot could then be asked to rate only the situation flown, (clear day to a runway), or alternately, the pilot could be asked to extrapolate the clear day observations into a dark, wet night environment.

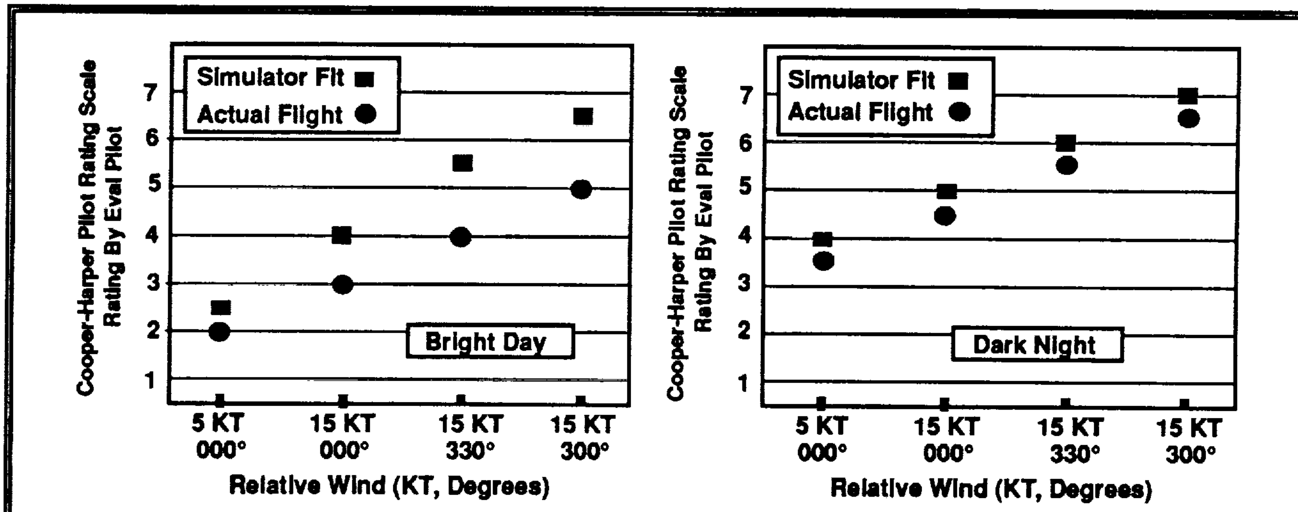
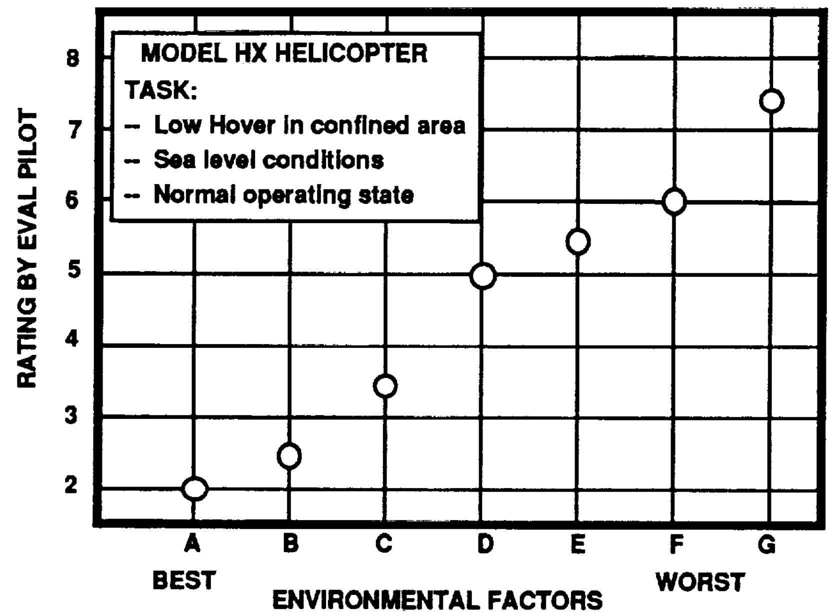


Figure 6: Comparison Of Pilot Ratings To Evaluate A Simulation Facility



A. Clear Day, Calm Air. B. Clear Day, 10 KT Rt Cross Wind. C. Clear Day, 10 KT Rt Cross Wind, Gusting to 17 KT
D. Night, Full Moon, Stars, Landing & Hover Lights, 10 KT Rt Cross Wind, Gusting to 17 KT.
E. Night, 1/4 Moon, Single Landing LT, 10 KT Rt Cross Wind, Gusting to 17 KT.
F. Night, Overcast, no surface lights, single landing Lt, 10 KT Rt Cross Wind, Gusting to 17 KT.
G. Night, Near Thunderstorm, 20 KT Wind, Gusting to 30 KT.

Figure 7: An Example Set of Progressively More Difficult Environmental Conditions Which Can be Evaluated in the Real World and Replicated in a Simulator to Collect Pilot Ratings for Evaluation of a Simulation Facility

Cooper-Harper agree that a pilot can extrapolate this experience and provide a rating for an environment worse than that observed in a hands-on evaluation. This of course assumes that the pilot has acquired an adequate understanding of the aircraft and is familiar with the operational environment of interest. Cooper-Harper go on to ask the question "... if the pilot doesn't do it, who will?". They also go on to conclude that an experienced pilot is probably the best qualified to extrapolate simulator experience into the real world.

The same ability to extrapolate has been recognized and utilized in the military and FAA evaluations of aircraft for at least forty years. That is, an experienced pilot is often asked to conclude in a few flights, that a given aircraft is, or is not, suitable for flight into instrument conditions without ever flying into instrument conditions. Regardless of the approach taken, the pilot and engineer should agree on which approach they will use and this selection should be reported with the data. This note of caution is supported by Harper and Cooper in Reference 1.

WORKLOAD AND INTEGRATED EVALUATIONS

With the increased use of computer based systems, the pilot's task has shifted more and more towards the overall flight management function. In minimum crew (one or two place) military combat aircraft, these system advances have added to the mission system functions over which the pilot has direct control. For military aircraft, the same technology advances have greatly expanded the functions of non-pilot air crew mission system operators - and increased the thrust towards the use of a minimum crew.

On the civil side, there is the potential of single pilot IFR helicopter operations, including approaches to busy airports and slow speed steep approaches into confined landing sites. These operations bring a similar concern for increased cockpit complexity and higher workload.

Workload

These developments have increased the attention of specialists in human task performance to the measurement of pilot and air crew workload, with recognition that in-flight measurement is needed to fully characterize the actual experience. Issues of objective vs. subjective measurement have received continuing attention in this field as elaborated in References 12 and 13. Due to the complexity of the total in-flight workload and the intrusiveness of available objective measurement techniques, there has been increasing acceptance of and support for subjective measurement.

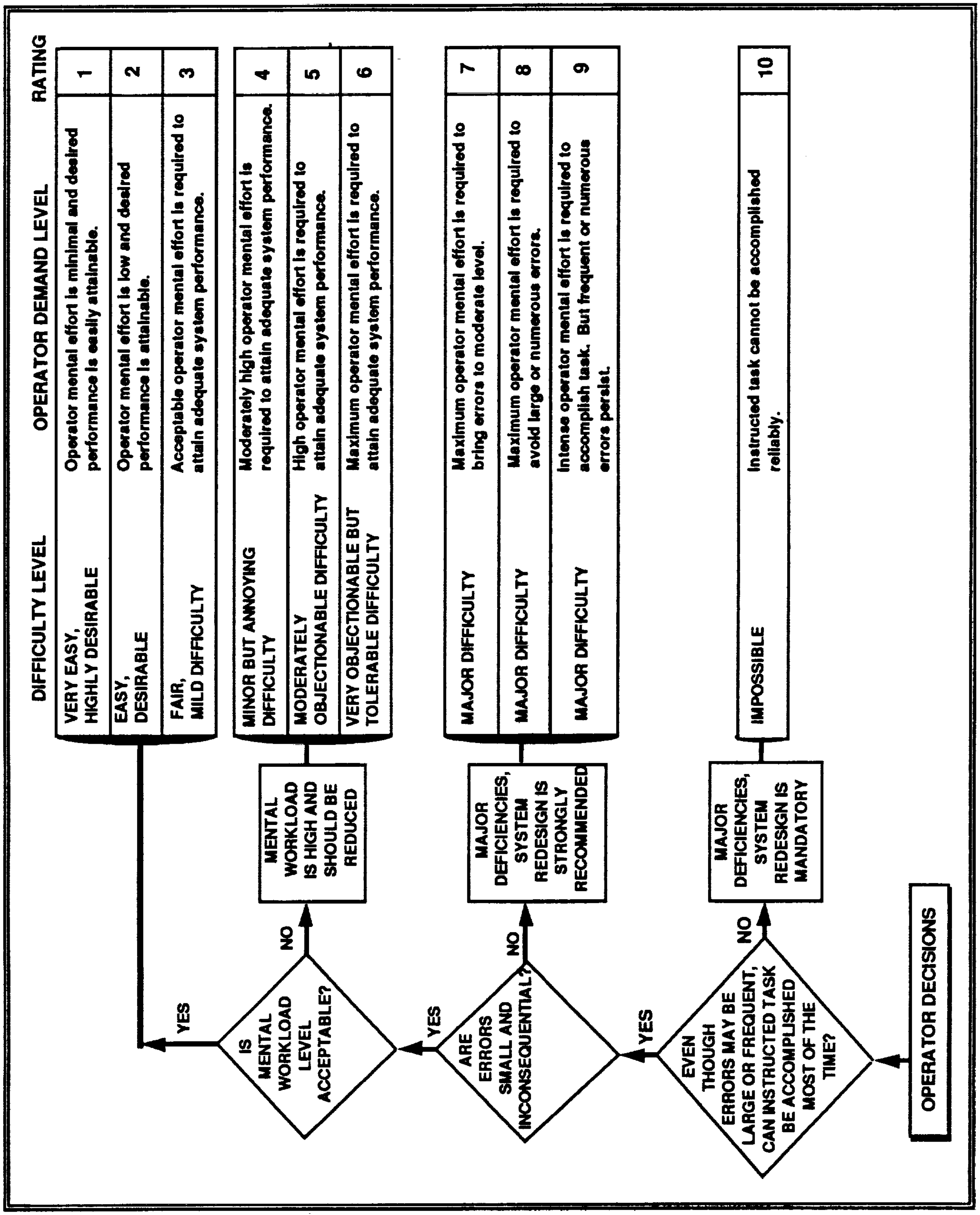


Figure 8: Modified Cooper-Harper Scale

Subjective measurements schemes that have been evaluated (Reference 14) indicate that some of them, while useful in laboratory investigations of pilot or operator workload, are quite cumbersome and too time consuming in ground based flight simulator or in-flight use. Chambers and Hilmer in Reference 14 clearly show the advantages of Weirwille's proposed Modified Cooper-Harper Rating Scale (MCHRS) (Figure 8) for workload assessment in both piloting and non-piloting tasks in these applications. The brief treatment in that paper, however, does not go on to point out other benefits of its use for these applications.

For example, the familiarity of engineering test pilots, simulation staff and flight test engineering personnel with the CHPRS provides a direct carry over to use of the MCHRS. This should allow its use in both workload measurement per se and in the evaluation of non-piloting flight management and mission systems, either individually or as part of the integrated overall pilot/pilot and mission specialist task. In the case of these applications, strictures similar to those which accompany the CHPRS would have to be developed. This would including the need for subject comments similar to those provided by pilots in the CHPRS.

Need For Single Integrated Rating

While separate assessments of handling qualities and workload can be useful in research investigations, for example Reference 15 contains the results of one such effort, this approach fails to give the decision maker a readily usable answer regarding operational suitability.

Decision makers need an overall rating which reflects the total suitability of the aircraft to accomplish its mission when operated by the typical air crew for which the aircraft was designed. For civil aircraft, FAA certification is the final go/no go decision. For military aircraft, the formal Operational Evaluation is the final stamp. But the use of the CHPRS to primarily evaluate flying qualities (with consideration of flying and CM workload inferred) and the use of the MCHRS as a sub-set to the CHPRS to evaluate workload, does not provide the desired single rating. It also fails to deal with comparative priorities (e.g., the flying task vs. the CM task). Another approach is needed.

INTERPRETED COOPER-HARPER PILOT RATING SCALE

Introduction

The preceding discussion has suggested that there is a need to apply the CHPRS more broadly while observing the strictures more diligently. This includes the need for a scale which is easier for operational pilots to use and which treats workload a bit more directly. This need includes both flying and the non-flying, cockpit management workload and the related priorities. In addition, there is the need to define half pilot ratings.

An example of how all of this might be accomplished is presented in Figure 9. The Interpreted Cooper-Harper Pilot Rating Scale (ICHPRS), as addressed here, is meant to have the same meaning as the original CHPRS of References 1 and 4. The concept also applies to the entire scale, but a complete treatment is beyond the scope of this paper. When compared to the CHPRS in Figure 1, it is quickly obvious that the first "pilot decision" steps are not included in Figure 9. In military version of this scale, these pilot decisions steps would be retained. In the civil version, they might not be retained (as suggested in Reference 16).

Half PRs

As discussed earlier, half PRs accomplish two objectives. First, they allow pilots to evaluate a condition or situation which does not meet the definition of a whole number in the CHPRS. Second, the half ratings allow the pilot or analyst to build a higher degree of confidence as to where the boundaries of interest are located. But the CHPRS does not provide definitions and, depending upon the application, this can represent a serious problem.

In contrast, the ICHPRS does include definitions for half ratings. These half ratings relate to the preceding whole integer rating and not to the subsequent rating. The logic of this approach is more apparent when one considers the transition between PRs of 3 and 4, and the PRs of 6 and 7 (especially when considering many of the military applications). Civil evaluators may draw the lines of suitability elsewhere with the same concern.

"Use Unique" Interpretative Narrative

The narrative in Figure 9 is meant to suggest an approach, not "the only" or "the recommended" approach. In most cases, the narrative in the ICHPRS should be developed by one or more engineering test pilot(s) and engineer(s) familiar with the test aircraft, its operational characteristics, and its operational requirements. This should produce one or more aircraft-mission unique scale(s), depending upon the scope of the evaluation.

The added descriptors might evolve during the initial shake down of an aircraft or during a familiarization period in the aircraft or in a simulator (if a real aircraft is not available). In any event, the use of a trained engineering test pilot, familiar with the Cooper-Harper scale, is strongly recommended.

Note that the descriptions under "Aircraft Characteristics" in Figure 9 are identical to those found in the CHPRS presented in Figure 1. The narrative under "To Achieve the best attainable performance" has two parts. The first part (left column) repeats the descriptions found in the CHPRS. The second part (right column) is split into two horizontal boxes. These two boxes contain the interpretive narrative for one whole PR and the associated half pilot rating. Note that this second column contains comments relating to both flight control and CM tasking, including indications of priority and performance.

The final column (under Representative Observations) amplifies the preceding descriptions of the pilot effort required by characterizing performance in terms of operational suitability. Here, examples are provided to aid the pilot in efforts to discriminate. As described in References 1 and 4, failure to meet the intent of any specific rating forces the pilot to assign the next higher rating.

Performance. Performance objectives must be defined prior to commencing an evaluation. These objectives must relate to tasks for which the pilot expects to achieve minimum error, or for situations where the pilot desires to maximize time out of the loop to rest or to conduct a CM task during which some amount of flight path error is acceptable. For example, this might characterize the shared monitoring of the aircraft's flight path and a mission equipment display.

In this regard, CM tasking could to be evaluated to determine the critical tasks and the procedures which apply. What CM tasks must be accomplished during high gain flight control events? This includes consideration of failure modes. For example, if an engine fails, is the pilot expected to continue the task and deal with the emergency procedures, or does the pilot first transition to a new flight phase?

The interpretative narrative can include detailed references to performance expectations or objectives for both the flying and the CM tasks. That is, there is no reason why performance objectives should not be inserted in the narrative. It seems likely that this approach would reduce the potential for variance, but in some situations, this level of detail would probably not be necessary.

Definitions. Once the performance objectives have been defined, and the narrative has been drafted, definitions should be developed and supported with examples where required.

Performance Priority. The narrative in Figure 9 was developed with the idea that the flight path performance of the aircraft was the primary or critical objective. It is also possible to have situations where CM is of paramount concern. The narrative would be written appropriately for such flight phases to reflect these changing priorities. For example, it may be important accomplish an electronic warfare task in a very precise and timely way, while operating at altitudes and speeds which minimize concern for flight path error.

AIRCRAFT CHARACTERISTICS	DEMANDS ON THE PILOT IN SELECTED TASK OR REQUIRED OPERATION *			PILOT ** RATING
	To Achieve the best attainable performance.		Representative Observations	
Minor, But Annoying Characteristics	Desired performance requires moderate pilot compensation.	Pilot must concentrate on flight path errors. CM tasks are accomplished following standard procedures.	Occasional relaxed control is possible, but workload sometimes results in unwanted deviation. Pilot is impatient and fatigued during extended operations.	4
		Pilot must concentrate on flight path errors. CM procedures are altered to accommodate reducted pilot capacity to monitor cockpit status.	Relaxed control is unachievable. Considerable compensation sometimes required. Pilot quickly impatient, quickly fatigued. Not accepted as the norm for the duration of routine or probable flight.	4.5
Moderately Objectionable Characteristics	Adequate performance requires considerable pilot compensation.	Pilot attention is fully focused on early error detection. Pilot is often unable to effectively plan and execute cockpit management tasking in accordance with standard procedures.	Performance is marginal for a precision task and is not acceptable for routine or probable operations. Pilot does not have the time to adequately monitor status of CM tasking.	5
		Concentration on error detection and compensation is intense, and approaching limit. Many cockpit management tasks are deferred, some are precluded.	Maximum acceptable compensation is required. Unusual attitude may develop while accomplishing CM task. Pilot is confident of success during 15 min precision and 120 min of improbable operations pursuing a non-precision.	5.5
Very Objectionable But Tolerable Characteristics	Adequate performance requires extensive pilot compensation.	Concentration on flying task is at limit. Critical CM activities are accomplished randomly, as opportunities arise during momentary improvement in flying task performance.	Excessive pilot compensation is required to continue marginally safe operations for 5 min in precision task and 30 to 60 min in non-precision tasks. Pilot is occasionally alarmed at combinations of error, error buildup rate and total workload.	6
		Concentration on flying task is at limit. Adequate flight performance can not be attained if any CM tasking is undertaken.	Compensation is at limit. Acceptable performance will probably only be achieved during very brief periods ranging from seconds to a minute. Pilot will persist only if there is no safer alternative. Aircraft will probably not be damaged is pilot persists. If pilot attempts CM task, aircraft may incur minor damage.	6.5

* Definition of required operation involves designation of flight phase and sub-phases with accompanying conditions.

** If a mission-flight critical cockpit management task can not be accomplished in a timely and effective way, the PR = 7.

Figure 9: An Example of Interpretive Narrative Added to a Portion of the Cooper-Harper Pilot Rating Scale

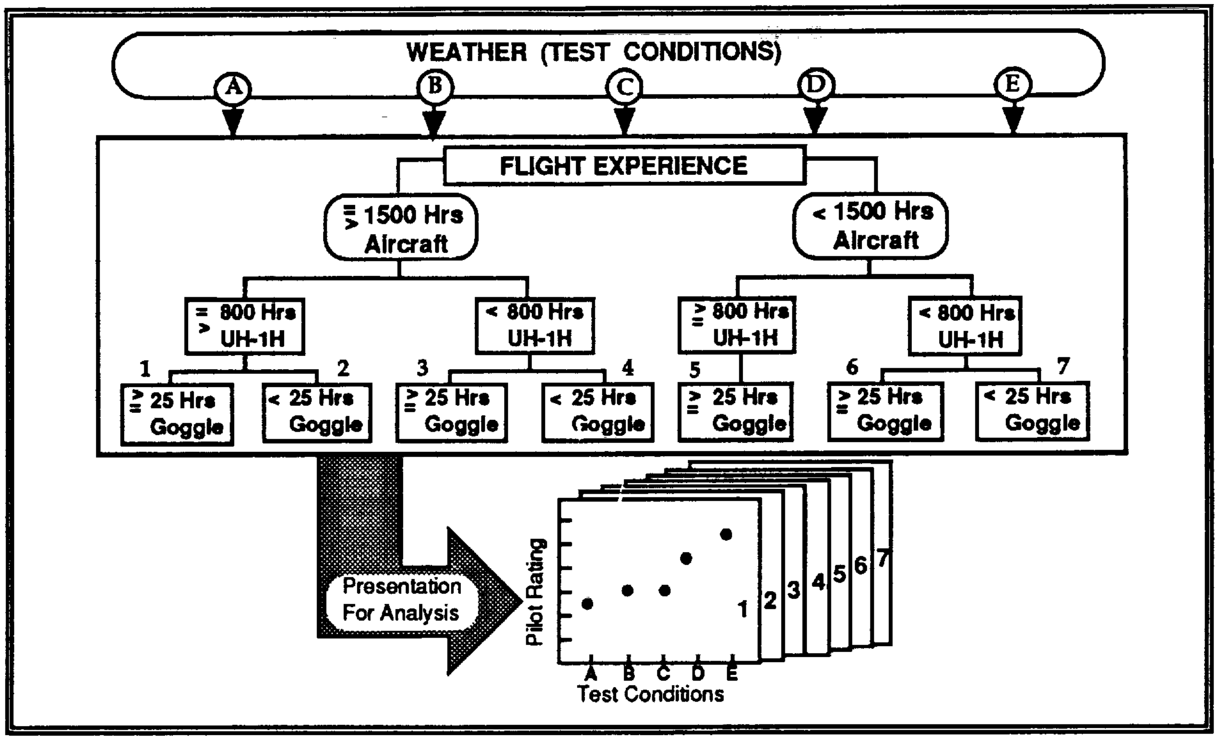


Figure 10: NVG Pilot Rating Analysis Classifications

NIGHT VISION TESTING BY FAA

This paper was in part made possible as the result of work funded by the FAA Rotorcraft Research Program Office in Washington, D.C., and accomplished in support of flight evaluations of night vision devices conducted by the Flight Test Division of the FAA Technical Center, Atlantic City International Airport, New Jersey. The objective of the evaluation was to provide an opportunity for a large number of civil and FAA pilots to fly with night vision goggles (NVGs) to determine their suitability for use by EMS operators.

This evaluation was chartered to use a group of civil helicopter pilots with dissimilar flying backgrounds to examine the safety of flight issues associated with the use of NVGs while operating in a variety of environments. For example, a variety of lighting environments and obstructions to visibility were of interest. --- None of the evaluation tasks involved Nap of the Earth (NOE) flying techniques.

As a result, a set of evaluation guides (booklets) were developed to help introduce pilots to the evaluation, and to help them understand an early ICHPRS. (References 17, 18, and 19). The interpreted pilot rating scale was meant to be faithful to the intent of the CHPRS. This project is currently underway and the results are yet to be documented. --- The current plan is to sort the pilot rating assessment data and compile the results for each task in a way which is characterized above in Figure 10. This should provide decision makers with data they need to determine suitability in terms of pilot experience and environmental factors.

CONCLUSIONS AND OBSERVATIONS

Cooper-Harper is an effective subjective assessment tool when applied in accordance with its creators full instructions. Extensive successful use in the past, and the evolving "test and approval decision processes" are areas where its effectiveness can be enhanced for current and future applications.

The ability of pilots to extrapolate pilot ratings is a well proven capability which is essential to safe, affordable and timely evaluation of aircraft and simulations of proposed aircraft designs.

A suitably tailored Interpreted Cooper-Harper Rating Scale as proposed will provide pilots not having an engineering test pilot background with an effective rating system for use in simulations and final operational evaluations.

The effectiveness of using Cooper-Harper in handling qualities evaluations, where workload is a factor in the assessment, strongly supports the use of a proposed Modified Cooper-Harper, appropriately adapted, in specific subjective workload assessment and non-pilot airborne system evaluations.

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