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THE USE OF PILOT RATING IN THE EVALUATION OF AIRCRAFT HANDLING QUALITIES

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SUMMARY

Pilot rating scales and their use in assessing aircraft handling qualities are reviewed historically, and objections that have been raised to limitations of earlier scales are considered in the development of a revised scale. Terminology used in the evaluation of handling qualities is reviewed and new definitions are proposed to improve communication and international understanding. Of particular significance is the new definition of handling qualities, which emphasizes the importance of factors that influence the selection of a rating other than stability and control characteristics.

The experimental use of pilot rating is discussed in detail, with special attention devoted to (1) clarifying the difference between mission and task, (2) identifying what the rating applies to, (3) considering the pilot's assessment criteria, and (4) defining the simulation situation. The important elements of the report are then summarized in a suggested "Briefing Guide," designed for guidance in planning and executing handling qualities experiments.

INTRODUCTION

The widespread application of pilot rating scales in the evaluation of aircraft handling qualities has confirmed their basic utility, but has, at the same time, exposed some weaknesses of the scales as originally proposed. It was therefore considered desirable to re-examine existing rating scales with the purpose of developing a single improved scale and of clarifying its use in the evaluation of handling qualities. In response to an invitation from the Flight Mechanics Panel, AGARD, a paper entitled, "A Revised Pilot Rating Scale for the Evaluation of Handling Qualities," was prepared and presented at the September 1966 meeting (ref. 1). A longer version of this paper (ref. 2) contains some additional explanatory discussion of the use of pilot rating scales. Additional constructive criticism was then based on experience gained with this revised scale.

In general, the revised scale was preferred over earlier scales, but constructive criticism from many research and development groups also indicated the need for additional changes or clarifying discussion. Difficulties, for example, were experienced with the semantics in that certain words had rather different connotations in the United States, England, and in France. The purpose of this report, then, is to clarify and modify, as appropriate, the material presented in references 1 and 2. One of the first objectives of the present report is to define precisely the basic terminology and explain the new features in the scale. The report goes on to discuss the more important factors that are considered by the pilot in the selection of a rating or that will otherwise influence the rating. Throughout the discussion, attention is directed to the questions: (1) what is the pilot being asked to rate?, and (2) how will the experimental results be used? The answers to both questions have important bearing on the interpretation of evaluations made by pilots with different backgrounds, experience, and points of view. The final section of the discussion is devoted to a review of certain other considerations that are helpful in the design of handling qualities experiments and to the use of pilot rating. The important elements of the report are summarized in a condensed "Briefing Guide" for use in planning and executing handling qualities experiments.

DISCUSSION OF HANDLING QUALITIES

Clarification of Terms

For a pilot rating scale to be universally acceptable and consistently applied in the evaluation of handling qualities, the terminology must be easily understood by all persons working in the field. Those terms requiring specific attention are defined in appendix A, and several definitions are suggested that may help clarify and standardize the terminology. Some of the terms suggested in reference 3 have been adopted in this report. Those most significant to a discussion of handling qualities are examined in considerable detail in the following paragraphs. Others are discussed as the need arises.

Handling qualities.- The term "Handling Qualities" requires a clear definition in order to emphasize that it includes more than just stability and control characteristics. Other factors that influence the handling qualities are the cockpit interface (e.g., displays, controls), the aircraft environment (e.g., weather conditions, visibility, turbulence) and stress, the effects of which cannot readily be segregated. Thus in most tests, handling qualities are really being evaluated in the aggregate.

In appendix A, "Handling Qualities" is defined as "those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role." The generally accepted meaning of "Flying Qualities" is similar to this definition of "Handling Qualities," so only the latter term is used in this report.

Figure 1 illustrates the factors besides stability and control that influence handling qualities. Here the primary elements of the pilot control loop are arranged to illustrate their relationship to the operation of the pilot-vehicle combination. In addition to the pilot, the task, and the stability and control characteristics, factors shown as influencing closure of the pilot control loops are the cockpit interface, the aircraft environment, and the pilot's stress.

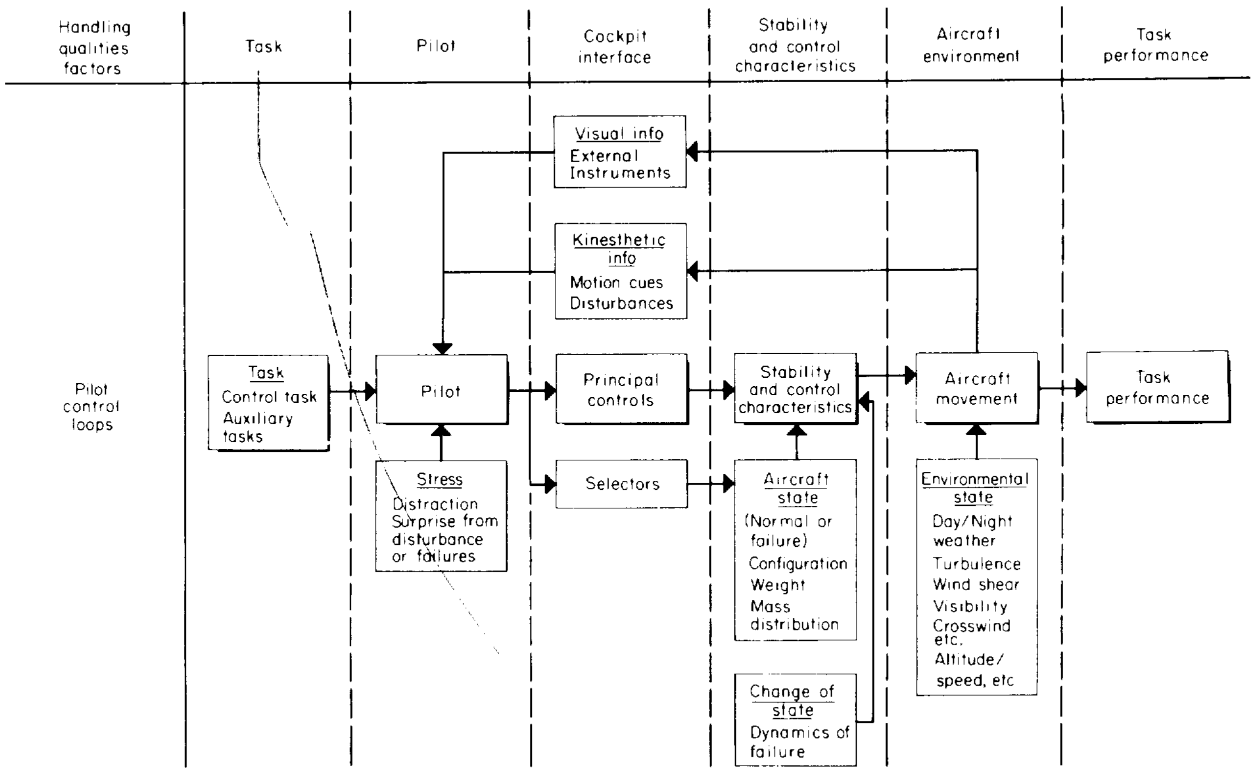

Figure 1.- Elements of control loop that influence handling qualities.

Mission.- The term "mission" has been used in the United States rather loosely, and may actually have several meanings, depending on how it is used. "Mission" has been used to identify, in a general sense, the purpose or objective for which an aircraft is built. It has also been used to designate a complete flight or sortie or even an undefined part of the flight. By inference, this undefined part is usually the special flight phase during which the primary assignment is carried out.

To avoid this ambiguity, the terms "role," "flight" or "sortie," "flight phase," and "flight subphase" are defined for use in place of "mission" (or mission element). The continued use of "mission" in relation to handling qualities, however, makes it worthwhile to have an acceptable definition. One that has been suggested (ref. 4) is "the composite of pilot-vehicle functions that must be performed to fulfill operational requirements." In the present report, "mission" is a general term used to convey this concept of "operational requirements," that is, the objectives or delineation of what it is that the pilot-vehicle combination must be able to accomplish. As a rule, the mission objectives (required operations) are cited in more detail as the flight segment (flight phase or subphase) of interest becomes more specific. The distinct differences intended between "mission" and "task" will be clarified in the following paragraphs.

Task.- The term "task" also has various connotations. We are concerned here only with the pilot's task, which includes controlling the aircraft as well as associated functions, not directly related to controlling the aircraft, such as navigation and communications. A task in the sense that it is used in handling qualities evaluations is defined as "the *actual work* assigned a pilot to be performed in completion of, or as representative of, a designated flight segment." In being representative of a flight phase, for example, the important pilot-vehicle functions required to fulfill the operational requirements for that flight phase would be represented in the task. Use of "task" and "mission" differs then, in that a task represents what the pilot is *actually asked to do* (as in a simulation task) while a mission refers to all operational requirements the pilot-vehicle combination *must be able to accomplish* if the "intended use" of the aircraft is to be fulfilled.

It is convenient to consider the complete task to be composed of (1) the control task, and (2) auxiliary tasks. The control task requires actuation of the principal controls and the selectors as required. The auxiliary tasks involve the pilot in actions other than direct control of the aircraft.

Flight phase.- The terms "flight," "flight phase," and "flight subphase" denote the flight profile of an aircraft and its subdivision into convenient segments. The delineation of aircraft role and the division of a complete flight into discrete segments for more definitive examination is illustrated in figure 2. Representative examples of what is meant by aircraft role, complete flight, flight phase, and subphase are given in this figure as well as in appendix A. A subphase is defined as "that part of a flight phase having a single objective, and a single configuration or change in configuration." A subphase evaluation then would provide a direct correlation between a specific set of stability and control parameters and pilot rating.

In summary then, the *role* of an aircraft defines its intended use only in a general sense. The *mission* delineates this use in terms of specific objectives, that is, the required operations of the pilot-vehicle combination. The *task* delineates those aspects of the mission that are work assigned to the pilot.

Methods of Determining Aircraft Handling Qualities

The relationship between stability and control parameters and the degree of suitability of the airplane for the mission may be examined by:

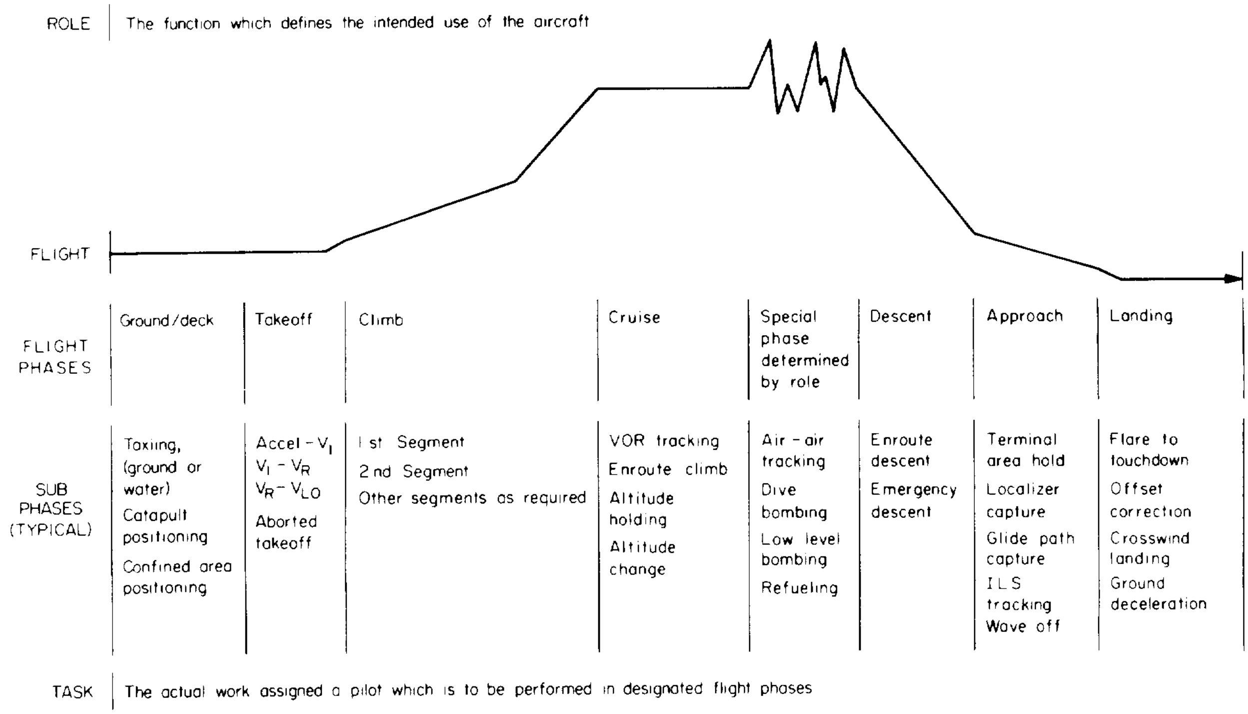

Figure 2.- The relationship between role, flight segments, and task.

1. Theoretical analysis
2. Experimental performance measurement
   a. Pilot input
   b. Pilot-vehicle output
3. Pilot evaluation

Each approach has an important part in the complete evaluation. One might ask, however, "Why is the pilot assessment necessary?" The answer must consider the two alternatives, theoretical analysis and performance measurement. At present, the applicability of the mathematical analysis including representation of the human operator is restricted to the analysis of specific simple tasks. Since the intended use (mission) is made up of several tasks and several modes of pilot-vehicle behavior, it is difficult first to describe accurately all modes analytically, and, second to integrate the quality in the separate tasks into a measure of overall quality for the intended use. Theoretical analysis is fundamental to the analytical prediction of handling qualities, but cannot adequately treat the complex interactions that are now investigated by means of experimental pilot evaluation.

The attainment of satisfactory performance in fulfilling a designated mission is, of course, a fundamental reason for our concern with handling qualities. Why, then, cannot the experimental measurement of performance replace pilot evaluation? Why not measure pilot-vehicle output performance in the intended use? Isn't good performance consonant with good quality? Unfortunately, the answer to the latter question is "not always."

A significant difficulty arises here in that, first, the tasks selected for measuring performance may not demand of the pilot all that the real mission demands, especially in terms of distractions, auxiliary tasks, and pilot stress. In the second place, pilot performance must also be measured and interpreted so that the pilot-vehicle performance can be evaluated correctly. The pilot is an adaptive controller whose goal (when he is so instructed) is to achieve good performance. In a specific task, he is capable of attaining essentially the same performance for a wide range of vehicle characteristics, at the expense of significant reductions in his capacity to assume other duties and to plan subsequent operations. Significant differences in his task performance may not be measured when very real differences in mission suitability do exist. The pilot's performance must be measured and analyzed properly to show these differences, and one must have a clear appreciation of what constitutes objectionable inputs.

In the third place, it is difficult, if not impossible, at the present time to measure all important aspects of pilot performance. Encouraging results have been obtained in specific instances (refs. 5-7) wherein good correlation has been obtained between measurements of the *physical* effort exerted by the pilot (i.e., integral of pilot control displacement, force, etc.) and pilot rating. In such cases, it must be assumed that differences in *mental* effort and attention were not significant. Rather than attempt to prejudge the influence of mental effort and attention, the term workload is defined to include both mental and physical effort. The use of modifying terms will be necessary then when a distinction is necessary between mental and physical workload.

The questions that arise in using performance measurements may be summarized as follows: (1) For what maneuvers and tasks should measurements be made to insure fulfillment of the mission objectives? (2) How do we integrate and weigh the performance in several tasks to get an overall measure of quality if measurable differences do exist? (3) Is it necessary to measure or evaluate pilot workload for the performance to be meaningful? If so, how are these factors weighed with those in (2)? (4) What disturbances and distractions are necessary to provide a realistic workload for the pilot while his performance in a specified task is being measured? The difficulties encountered in answering each of these questions provide some of the reasons why continued reliance upon pilot evaluation is necessary and why much of the detailed discussion is included in this report. Although the use of measured task performance is not discussed further in this report, continued efforts to measure and interpret both the pilot performance and the pilot-vehicle performance should be encouraged. Such information is important to the understanding of pilot adaptation or "learning curves," and to the interpretation of pilot evaluation data.

Pilot evaluation still remains the only method of assessing the interactions between pilot-vehicle performance and total workload in determining suitability of an airplane for the mission. It provides a basic measure of quality and serves as a standard with which pilot-airplane system theory may be developed, performance measurements may be correlated, and significant airplane design parameters and characteristics may be determined and correlated.

Pilot evaluation data generally consists of: (1) the pilot rating, or shorthand representation of the flying characteristics as they relate to mission accomplishment, and (2) the pilot comments that identify those characteristics that interfere with the intended use.

A pilot rating is a portion of the technical report of the evaluator, and is the overall summation of the suitability of the vehicle for the specified use. The pilot rating scale is then a systematic means of denoting the quality of the pilot-vehicle combination in the accomplishment of its intended purpose.

EARLY RATING SCALES

In early handling qualities research, each investigator tended to develop a rating scale peculiar to the needs of his specific program, or to modify an existing one. With experience, certain pilot rating scales proved successful and stimulated further interest in them. Two such early scales are discussed here.

In reference 8 the original Cooper Scale (fig. 3) proposed the basic framework of boundaries that is still the foundation of most pilot rating scales, including the presently proposed one. This framework involves several grades of quality pertaining to the intended use of the vehicle.

Acceptable and Satisfactory - sufficiently good
Acceptable but Unsatisfactory - not sufficiently good, but still usable
Unacceptable - not usable for mission
Uncontrollable

	Adjective rating	Numerical rating	Description	Primary mission accomplished	Can be landed
NORMAL OPERATION	Satisfactory	1	Excellent, includes optimum	Yes	Yes
		2	Good, pleasant to fly	Yes	Yes
		3	Satisfactory, but with some mildly unpleasant characteristics	Yes	Yes
EMERGENCY OPERATION	Unsatisfactory	4	Acceptable, but with unpleasant characteristics	Yes	Yes
		5	Unacceptable for normal operation	Doubtful	Yes
		6	Acceptable for emergency condition only*	Doubtful	Yes
NO OPERATION	Unacceptable	7	Unacceptable even for emergency condition*	No	Doubtful
		8	Unacceptable - Dangerous	No	No
		9	Unacceptable - Uncontrollable	No	No
	Unprintable	10	"Motions possibly violent enough to prevent pilot escape"		

* Failure of stability augmenter

Figure 3.- Original Cooper Rating Scale.

Important contributions of the early scales were to emphasize pilot acceptance of handling qualities with respect to the intended use by:

a. Encouraging investigators to define adequately the program objectives and the intended use of the aircraft.
b. Firmly establishing within the scale the acceptable-unacceptable, and satisfactory-unsatisfactory boundaries.
c. Creating a logical basis that would enable the pilot to express his assessment accurately and consistently.

The original Cooper Scale included too many different concepts. The introduction of stability augmentation and undefined failure modes, of normal and of emergency operation, and the separation of the landing task from the primary mission led to ambiguous interpretations.

Category	Adjective description within category	Numerical rating
Acceptable and satisfactory	Excellent Good Fair	1 2 3
Acceptable but unsatisfactory	Fair Poor Bad	4 5 6
Unacceptable	Bad* Very bad** Dangerous'	7 8 9
Unflyable	Unflyable	10

*Requires major portion of pilot's attention
**Controllable only with a minimum of cockpit duties
'Aircraft just controllable with complete attention

Figure 4.- CAL Rating Scale.

The CAL scale of figure 4 was developed primarily because the Cooper Scale was confusing to some in that it could be interpreted as introducing an alternate mission concept. Separate boundaries were shown in the Cooper Scale for normal operation and for an undefined emergency condition. By removing this doubt of mission completion in the adjective descriptions in the acceptable range, as well as removing all consideration of an alternate mission from the scale itself, the CAL scale clarified this situation. However, the very simple descriptions of the CAL scale are not considered particularly helpful by many pilots and the dual use of "fair" and "bad" was confusing to some.

Having now identified certain deficiencies and objections to two rating scales and clarified some of the terminology, we are in a position to construct a revised scale.

REVISED PILOT RATING SCALE

Major Categories

Category selection.- The Cooper and CAL Rating Scales and the revised scale proposed in references 1 and 2 have the same basic structure. The major categories are identified as "satisfactory" and "unsatisfactory," or "acceptable," "unacceptable," and "uncontrollable." Such terms relate only to the *individual pilot's* assessment of quality relative to the intended use of the aircraft. The intention has been to encourage the *pilot* to make the important decisions identified with these terms. These categories are systematically arranged so that the pilot can choose between two alternatives that lead to the proper category.

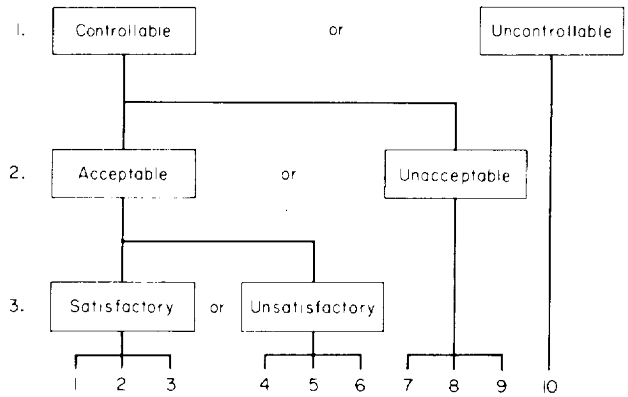

Figure 5.- Sequential pilot-rating decisions.

This structure is illustrated by the flow chart in figure 5, which enables one to trace the series of dichotomous decisions the pilot makes in arriving at the final rating. As a rule, the first decision is fairly obvious. Are the handling qualities controllable or uncontrollable? To determine whether this decision applies throughout the task or flight phase and in context of the defined role may not be so obvious.

If the vehicle is uncontrollable, it is rated 10. If it is controllable, the second decision is whether it is acceptable or unacceptable. If unacceptable, the rating 7, 8, or 9 will be selected (rating 10 has been excluded by the "controllable" answer to the first decision). If it is acceptable, the third decision is whether it is satisfactory or unsatisfactory. If unsatisfactory, the rating 4, 5, or 6 will be selected; if satisfactory, the rating 1, 2, or 3 will be selected.

Category definitions.- The dichotomous decisions outlined in the previous paragraph logically lead to four categories of quality, some of which have been difficult to describe accurately by a single adjective. There are objections to the designation "unsatisfactory but acceptable" and "unacceptable but controllable," but no simple adjective descriptions for these categories have been found that will satisfy everyone. In spite of strong emphasis as to the need to establish clearly that the terms are related to the *pilot's own* assessment of acceptability and not to any existing standards, specifications, or other Acceptance Criteria, objection to "acceptable" and "unacceptable" in the scale remains.

Regardless of the terms used in a revised rating scale, it is necessary to clarify the intended meaning of satisfactory, unsatisfactory, acceptable, tolerable, unacceptable, controllable, and uncontrollable. Let us examine, first, what is meant by "controllable," even though it has caused less difficulty than the other terms. To control is to exercise direction of, to command, or to regulate. The determination as to whether the airplane is controllable must be made within the framework of the defined mission or intended use. An example of the considerations of this decision would be the evaluation of fighter handling qualities during which the evaluation pilot encounters a situation in which he can maintain control only with his complete and undivided attention. The vehicle is "controllable" in this situation in the sense that the pilot can maintain control only by restricting the tasks and maneuvers he is called upon to perform and by giving the configuration his undivided attention. However, for him to answer, "Yes, it is controllable in the flight phase (or task)," he must be able to retain control in all mission oriented tasks and other required operations without sacrificing effort and attention to his overall duties.

Consider now the meaning of acceptable, the usage of which has been the subject of some controversy, and the alternate suggested term "tolerable." The dictionary shows "acceptable" to mean that a thing offered is received with a consenting mind; "unacceptable" to mean that it is refused or rejected. Acceptable means that the flight phase (or task) can be accomplished; it means that the evaluation pilot would agree to use it for the designated role; that such deficiencies as may exist can be endured or tolerated. Use of the term "acceptable" does not say how good it is, but it does say the pilot considers it good enough for the intended use. With these characteristics, the flight phase (or task) can be accomplished with adequate precision. The task, for example, may be accomplished with considerable effort and concentration on the part of the pilot, but the level of workload required to achieve this performance is tolerable and not unreasonable in context with the intended use. By the same token, "unacceptable" does not necessarily mean that the designated flight phase (or task) cannot be accomplished; it does mean that the necessary performance cannot be achieved or that the effort, concentration, and workload required are of such magnitude that the evaluation pilot rejects the aircraft for this phase of its intended use.

Consider now a definition of "satisfactory." The dictionary defines this as adequate for the purpose, of a kind to meet all requirements or expectations. A pilot's definition of satisfactory might be that it isn't necessarily perfect, or even good, but it is good enough that he wouldn't ask that it be changed. It meets a standard; it has sufficient goodness; it's of a kind to meet all pilot demands for the intended use.

Unsatisfactory implies that there is insufficient goodness to meet all pilot demands; that it has deficiencies and objectionable characteristics which he feels should be corrected. Unsatisfactory includes all that is not satisfactory, just as acceptable includes all that is not specifically refused as unacceptable. A specific category is then that which is "unsatisfactory but acceptable." This category has previously been referred to by the shorter term "acceptable" but could also be referred to as "tolerable" in the sense, "capable of being borne, supportable, bearable." As a result of the possibility of the misinterpretation in the use of "acceptable" it has been found preferable to use "tolerable" rather than "acceptable" in the rating scale.

Thus, the quality is either:

a. Satisfactory - good enough without improvement, and, therefore, of the best category, or

b. Unsatisfactory but tolerable - just good enough, adequate for the purpose but improvement desirable, and, therefore, of the next best category, or

c. Unacceptable to the pilot - not suitable for the purpose but still controllable, and in the third category, or

d. Uncontrollable - unacceptable for the purpose and of the poorest quality and in the fourth category.

Inasmuch as only four categories of quality are needed to identify and describe handling qualities, it is possible to simplify the dichotomous decision process illustrated in figure 5 and eliminate "acceptability" terms.

By considering the following three decisions the pilot will arrive at one of the four categories previously discussed:

1. Is the vehicle controllable?
2. Is adequate performance attainable with a tolerable workload?
3. Is the vehicle satisfactory without improvement?

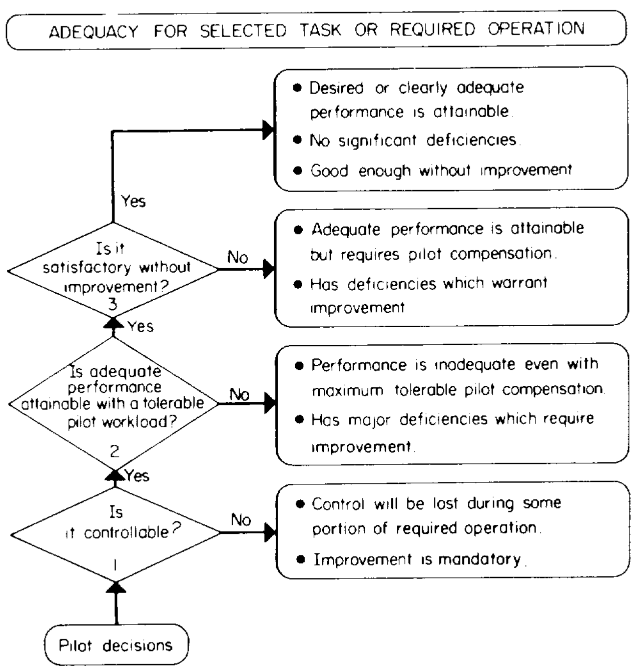

Figure 6.- Major category selection and definition.

Being able to designate a category by a single adjective was considered less important than that the definition of each category be precise. The rating scale now proposed is therefore based on the category definitions provided in figure 6. These are reasonably concise and emphasize the pilot's decisions involved in category selection.

Fundamental to this selection is the consideration of whether adequate performance is attainable in the selected task or required operation (mission) and whether or not deficiencies are present which require pilot compensation.

Assessment of task performance and pilot workload then enables the pilot to decide whether the handling qualities are good enough without improvement, have deficiencies for which improvement is desired, or have deficiencies for which improvement is essential.

Individual Ratings

The complete revised rating scale[1] in figure 7 includes further subdivisions of quality within three of the four major categories with appropriate descriptions for each numerical rating to define quality differences. These allow the pilot a sufficient range of handling quality descriptions for most situations. Repetition of descriptive terms from the category definitions has all but been eliminated in the individual rating descriptors.

[1]Small and large copies of figure 7 are available. Send requests to Technical Information Division, Ames Research Center, Moffett Field, Calif., 94035.

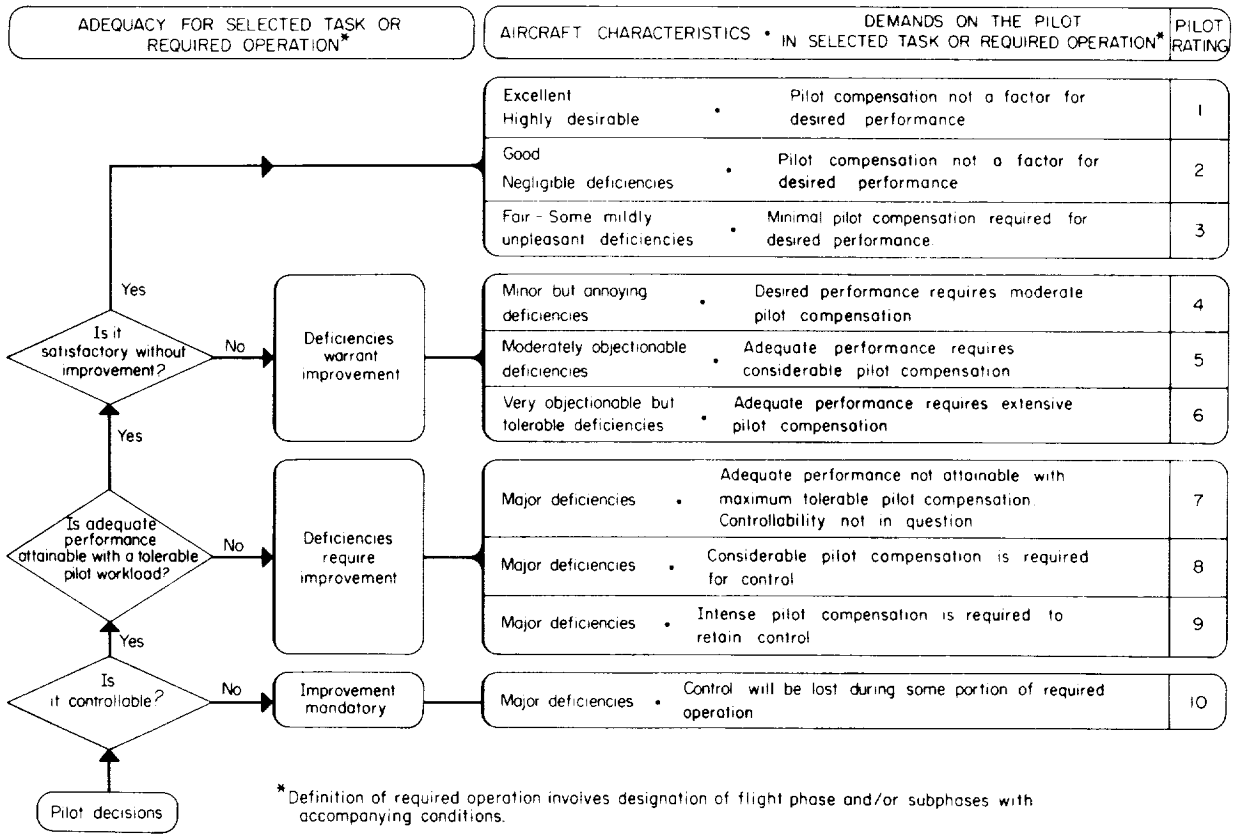

Figure 7.- Handling Qualities Rating Scale.

Considered desirable in simplifying the scale for the experienced user, this arrangement, however, makes it mandatory that any user understand and utilize the category definitions and make the decisions outlined on the left. The important "boundary" decisions between pilot ratings of 3 and 4, 6 and 7, or 9 and 10 cannot be made by reference to the individual rating descriptors alone. It is emphasized that these descriptions supplement the sequential decisions that lead the evaluation pilot to the particular category within which the descriptions of the individual ratings are given. It was considered fundamental to a good, easily applied scale that the descriptions be both brief and general. Key words and phrases were sought that would easily be understood and yet sufficiently definitive so that each rating would be clearly separated from every other rating. The following paragraphs discuss and explain some of the factors related to the rating scale.

Performance and workload.- Consideration was given to describing quality in terms of both performance (precision of aircraft control)[2] and workload (effort and attention)[2] for each numerical rating. Upon closer examination,

[2]When applied to handling qualities, the term "performance" alone is intended to mean the precision of aircraft control attained by the pilot, that is, the pilot-vehicle performance. The term "workload" is intended to convey the amount of effort and attention, both physical and mental, that the pilot must provide to attain a given level of performance. "Pilot performance" may be used to describe the measure of *physical* workload (effort and attention) used in performing a task.

however, it was concluded that these factors were so interdependent and subject to tradeoff by a pilot that it would be impossible to define non-conflicting individual ratings. Precision of control could not be defined independently of the amount of effort and attention required of the pilot for any task.

The best category is defined as *desired* or *clearly adequate* performance in association with a satisfactory level of pilot workload. The second best category is defined by achievement of *adequate* performance although the pilot is required to compensate for deficiencies by increasing his workload. It is *tolerable* to him but he desires improvement. The third category involves major deficiencies because the pilot finds it impossible to achieve adequate performance even though his attempt to compensate increases the total workload to the maximum tolerable in context of the task or mission. *Uncontrollable* obviates further concern with performance, but as in all previous categories, must also be considered in the context of the selected task or required operation (mission).

Compensation.- "Pilot compensation" as used in the scale is intended to indicate that the pilot must increase his workload to improve aircraft performance. It relates the pilot's difficulty in completing a task with the precision required for that task. Stated another way, it is the measure of additional pilot effort and attention required to maintain a given level of performance in the face of less favorable or deficient characteristics. The total workload is then comprised of the workload due to compensation for aircraft deficiencies plus the workload due to the task.

Referring to figure 6, we see that it is really only necessary to define that which constitutes *adequate* performance when answering the second question. The precision of control required for any task is most easily defined in terms of the end result obtained. For example, the approach performance can be specified in terms of the threshold "gate," and landing performance is measured in terms of vertical velocity at touchdown and dispersion about the intended touchdown point. The necessity for holding airspeed, altitude, flight path, or other parameters within specified limits throughout each flight phase or subphase may also be specified, but the cause and effect of occasionally exceeding the limits may require pilot interpretation. The pilot must balance both aspects of performance - maintaining precision of control and the end result - against his own effort and attention in arriving at a rating.

The category definitions of figure 6 recognize the interaction between performance achieved and the pilot workload required to compensate for deficient characteristics. In the best category, no significant compensation, in terms of added workload, is required by the pilot to achieve adequate performance. In fact, adequate performance is clearly achievable and it may just as easily be possible to attain some higher level of performance, such as might be designated broadly as *desired performance*. From the definition, it may be deduced that *desired*, or at least *clearly adequate*, precision of control can be obtained with relative ease or a low level of effort and attention. With deficiencies characterized by the second category, considerably more pilot effort is required and *desired* performance is not necessarily obtained. Now, however, a lower level of handling performance, but one *adequate* for the purpose, can be achieved as long as the pilot will increase his workload, even to the maximum tolerable for the selected task. If major deficiencies exist, *adequate* precision of control would require an excessive level of pilot workload and even the maximum tolerable pilot workload will not enable achievement of the level of performance that is considered *adequate* for the selected task. In this category, the additional deficiencies that increase demands on the pilot can only be expected to result in *inadequate* performance, and the primary question becomes one of controllability. The manner in which precision of control may be traded off against pilot effort and attention is complex and defies explicit definition for all flight phases or specified tasks. However, such compensation is available to the pilot and is probably involved in the evaluation of handling qualities.

Failures or emergency operation.- The revised scale contains *no* reference to failure considerations or emergency operation. In effect, this means that the pilot need not always concern himself during an evaluation with the probability of a failure, nor with the length of time he might be faced with deficient handling qualities. The time (duration) during which particular characteristics must be coped with is inherently defined by the role and the flight phase or task being evaluated. For operation based on a normal aircraft state, the duration can be based explicitly on the aircraft role. If a failure occurs, however, it may be necessary to consider alternatives like aborting the flight or changing the flight plan to permit retreat to a more favorable flight condition; in either case, the length of time that the critical flight condition must be tolerated might be shortened. Unless such alternatives are spelled out in the task definition, however, the pilot must always treat a failure state as having to be coped with for the duration of the task or flight phase, depending on which is being rated. Normal and emergency states then will require separate evaluations.

There are environmental conditions as well as minor failures which can limit aircraft operation without being identified as an emergency. Excessive turbulence or crosswind could preclude attempting a landing and thus require that the flight plan be altered accordingly. Whenever limitations to the operation are indicated or accepted in lieu of specifying a critical task this fact should be clearly noted.

Pilot skill.- The pilot effort and attention required for a given task or flight phase will, of course, depend somewhat upon individual pilot skill and state of training. In the early versions of the revised scale, the term "skill" was used in the 8 and 9 rating descriptions in consideration of the role of pilot skill in the degree of controllability which could be achieved. Further consideration, however, has led in the 8 and 9 rating descriptions to the substitution of phrases reflecting pilot workload required to even continue the task and the relative difficulty in maintaining control, in order to retain a consistency and compatibility with the rest of the scale. In this manner, pilot skill becomes a consideration of the total program for which the evaluation is being made.

It is the opinion of the authors that as a general rule each pilot should judge the suitability of any set of airplane characteristics in terms of his own skill and training, and in terms of the required operations and circumstances as defined in the experiment. The effects of differing skills should be determined from the results obtained from evaluation pilots of different, but representative, levels of experience and training. Exceptions to this general rule have occurred, however, when the research or development test pilot is asked to evaluate handling qualities with respect to his understanding of the lowest degree of skill and training existent in a group of operational pilots.

Operating margins and safety.- The question of safety cannot be separated from handling qualities because the precision with which certain parameters are controllable determines whether available safety margins are apt to be exceeded. The margins provided, as well as the consequence of exceeding them, will certainly influence the effort and attention which a pilot applies. Operating margins with respect to such parameters as airspeed, angle of attack, Mach number, and altitude then represent the constraints that define required precision of control, and thereby influence the rating selection. Operating margins and safety should be recognized as constraints upon handling qualities that are inextricably related to performance and workload.

Considerations Associated With the Structure of the Revised Scale

Why a 10-point scale?- In discussing the revised scale, one question that might be anticipated concerns the number of individual ratings the scale defines. Most simply, the number is related to the four categories already selected. Separating each of the upper three categories into three subratings appears to provide an adequate spread for pilot use. Additional ratings in the fourth category (uncontrollable) would not appear to be of general value. A change in the number of individual ratings for each category was not deemed necessary or desirable when considered in light of the large amount of experience with the previous scales.

Identifying the revised rating.- The oft-proclaimed criticism that the scale should start with 10 and progress to 1 instead of from 1 to 10 may be valid, but there are also examples that support the 1 to 10 logic. We are reluctant at this point to suggest a change simply because of the widespread use of 3-1/2 and 6-1/2 boundaries. To now reverse these would likely introduce considerable confusion and would not necessarily have long-range benefits.

In proposing a revised scale, it was recognized that some confusion might result from continued use of the same numerical scale that has been identified with both the Cooper and CAL Scales. In references 1 and 2, the authors proposed a modified identification system using letters A and U in conjunction with the numbers 1 - 9. Subsequent experience and comment indicated this to be unnecessary, as long as the rating numerals are associated explicitly with the particular scale used.

Linearity.- This is a desirable characteristic of any scale. A temperature scale is linear with heat added for a material with constant specific heat, in that the temperature rise per unit quantity of heat added is the same throughout the scale. Temperature is a normal and useful scale associated with comfort. Even though temperature may be quite linear with heat added, comfort is not linear with temperature. With what should the pilot rating scale be linear? Since it is purported to measure quality, it should then be linear with the added quality of the pilot-vehicle combination in that the change in pilot rating per unit quality addition should be the same throughout the rating scale. The rating scale may possibly have this characteristic, but to demonstrate that the scale is indeed linear would require an independent measure of quality that does not presently exist. Since the basic merit of the scale is not significantly affected by the lack of demonstrated linearity, this factor has not been considered further. McDonnell in reference 4 describes a study that establishes a correlation between the Cooper Scale, the revised scale of references 1 and 2, and a linear scale.

Ordinal versus interval scale.- An interval scale is desirable, but the proposed pilot rating scale cannot be shown to be an interval scale. The authors have accepted it as being ordinal. It is, however, primarily an absolute scale rather than a relative one. The pilot rating is given for a configuration in the context of its acceptability to the pilot for the specified flight phase (or task) and not in terms of its goodness with respect to a configuration already evaluated. Fortunately, the concentration and effort required in performing each evaluation tends to suppress in the pilot's memory the characteristics of preceding configurations, enabling him to consider objectively each configuration on its own merits for the required operations without continually making paired comparisons. Pilots are reluctant to rate something as excellent or optimum for fear that a subsequent configuration will be better than anything they considered possible.

Words versus numbers.- The basic structure of the rating scale is completely dependent on words and their explicit definitions. The numeral associated with the evaluator's final decision is an expedient, a shorthand symbol. One risk associated with a numerical scale is that engineers will attempt to treat the pilot rating data with mathematical operations that are rigorously applicable only to a linear interval scale. Although some insight is sometimes gained, analysis of specific pilot rating data should not be totally dependent on such mathematical operations.

Differing standards of acceptance for the same mission.- One difficulty that has arisen in the use of pilot rating data can be illustrated by the following example. In an evaluation program for the landing approach flight phase of a commercial air transport the role and mission were carefully defined, the program was run, and the results were reported. One of the evaluation pilots, an airline pilot, subsequently remarked that his airline would not accept any airplane with worse than a 4-1/2 rating for the landing approach. However, using the generally accepted interpretation of the rating scale, this pilot had said, as an evaluation pilot, that aircraft with worse characteristics which he rated at 5 and 6 could still be considered acceptable for the intended use. In the first case he was reflecting the viewpoint of airline management and not speaking from the pilot's standpoint. It must be recognized that the final determination of overall acceptability of an aircraft for a given role may be influenced by factors other than just the piloting rating of the handling qualities.

In deciding what to buy, any customer considers what he will get in terms of how much it will cost. It is easy to envision similar decisions being made to buy only that which is above the 3-1/2 boundary. And similarly, one can envision a reluctant decision to buy as low as a 6 rating, or to even accept a 7 or 8 rating (if the rating applied to a flight condition or aircraft failure state of low probability), but only if all other possibilities for purchase of a better aircraft had been excluded. The basic pilot rating data on which these decisions are based, however, must be strictly mission-oriented if the subsequent quality versus cost decisions are to be meaningful. That is to say, the role must be understood and each flight phase adequately defined by the piloting task(s) provided.

EXPERIMENTAL USE OF PILOT RATING OF HANDLING QUALITIES

In previous usage of pilot rating scales, too little attention has been given to defining just what the pilot was rating and how the data were to be used. In defining the experiment and in reporting the results, it became apparent that (1) the term "handling qualities" requires a tighter, less ambiguous definition, (2) an accounting is required for certain factors in addition to stability and control, (3) a clearer understanding is needed of the difference between mission and task definition, (4) certain considerations relative to the pilots assessment criteria must be understood, and (5) a simulation situation requires special definition and consideration of the use of the results and of the need for pilot extrapolation.

In the following paragraphs attention is devoted to certain aspects of the design and execution of handling qualities experiments that are considered particularly important to the production of good data and the further clarification of the aforementioned problems.

Program Development

Fundamental to any handling qualities program is a clear definition of the primary objectives of the program and of the role and mission of the aircraft. Next is the designation of the tasks to be used in the course of the evaluation, and what the rating applies to.

Program objective.- Generally, it is expected that the use of the data will conform reasonably well with the objectives outlined for the program. The primary objectives are related to either research, development, or acceptance but there may also be a number of special considerations. (These include whether the program is exploratory or expected to be highly definitive, etc.) It is essential to define whether stability and control characteristics or cockpit interface elements are the primary variables of investigation and whether special conditions such as environmental disturbances, dynamic or static failures, or stresses are to be included in the task or considered in the rating. Of particular importance will be the selection of evaluation pilots and their indoctrination with respect to the program. The particular background, training, experience, and point of view of the evaluation pilots selected for the program may be determined by the program objective as well as by the intended use of the resultant data.

Mission description.- The explicit description of the mission by delineation of the "required operations" is probably the most important contributor to the objectivity of the pilot evaluation data. The role must be carefully analyzed and a clear description and understanding reached between the engineer and the evaluation pilot as to their interpretation of the required operations. This description must include:

a. What the pilot is required to accomplish with the aircraft, and
b. The conditions or circumstances under which the mission is to be conducted.

Because of their importance in specifying "what the pilot rating applies to" and in providing definitive guidance for the pilot in his evaluation, the "required operations" may often have to be given in considerable detail. In its simplest form, this consists of designating the flight phase or subphase(s) of interest, and including such variations as are considered critical and representative of actual operations.

As an example of (b), the conditions or circumstances might include instrument or visual flight, type of displays or controls in the cockpit, or other input information to assist the pilot in accomplishing the mission, etc. The environment in which the mission is to be accomplished must also be defined and considered in the evaluation, and could include, for example, the presence or absence of turbulence, day versus night, the frequency with which the mission has to be repeated, the preparedness of the pilot for the mission, and the pilot's level of proficiency.

As noted under the discussion of the revised scale, it was recommended that steady-state failure considerations, with the attendant questions as to probability of occurrence, should be removed from the scale. This means that separate ratings would be obtained for each failure mode. Steady-state failure modes would then normally be considered as existing throughout the evaluation task or flight phase, unless, of course, a specific evaluation program is designed to consider them otherwise.

In evaluating the impact of transient disturbances caused by either environmental conditions or system failures, the pilot is still faced with the basic decision of what tradeoff he will accept between performance and workload and how long he must cope with the condition.

High probability occurrences, such as low to moderate turbulence, wind shear, and cross wind, can be rated separately, as if occurring throughout the task or flight phase, but should be included in a composite rating or a flight phase rating to convey the realistic situation. It is preferable to evaluate separately such low probability occurrences as severe turbulence so that the pilot is not asked to weigh probability of occurrence and generalize a composite rating to the point that it loses value. For example, a pilot may prefer to discuss a short duration occurrence of degraded handling qualities in the pilot comment data rather than to make a radical change in the task rating or flight phase rating.

Such questions of probability of occurrence and levels of disturbances must be resolved as part of the mission description in the design of the experiment, with special attention often being required with respect to pilot orientation and the reporting of results.

What the Rating Applies to

Task and flight phase terminology.- For a pilot to evaluate the handling qualities of an aircraft, he must maneuver it and otherwise use it for its intended purpose. This purpose is given in a general sense by the role but more specifically by the designation of the required operations or mission. Next, it must be decided whether the handling qualities are being evaluated for a complete flight, a single flight phase, a subphase, or a specifically defined task. In any event, a task or series of tasks must be specified that will provide a suitable basis for pilot evaluation. The extent to which the evaluation task selected represents all aspects of the aircraft mission will depend upon several factors, the more important of which are program objective, simulation capability, and certain pilot considerations. From the definitions provided, it will be possible to establish conventional procedures for referring to task ratings in contrast to flight, flight phase, or subphase ratings.

General considerations.- To provide an overall pilot rating for a complete flight or aircraft role would likely involve so many situations that little of the information would relate to specific stability and control characteristics. For such a use, an overall rating would be of little value unless reference were made to the detailed comments provided by the pilot for each subphase. A flight subphase, on the other hand, is devoted to a single objective and has a single configuration or change in configuration. Therefore evaluation of a flight subphase would enable more direct correlation to be made between pilot rating and specific stability and control characteristics.

Should significant changes then occur in either the aircraft state, the cockpit interface or the aircraft environment during a given flight phase, it might be desirable to confine the pilot rating to a flight subphase defined by a single aircraft state even though the task occurs in other subphases with different aircraft states.

If an evaluation is to apply to a flight phase, the rating will tend to be weighted by the more adverse subphase characteristics. On the other hand, a longer task representative of one or more flight phases will provide a better opportunity for the pilot to assess the workload involved, the adequacy of the information displayed, and the effect of unanticipated environmental disturbances.

Short term maneuvers, particularly if determined to be the critical part of the task, will be most useful when the effect of specific stability and control parameters are assessed, but their use to the exclusion of a long-term mission-oriented task can reduce both confidence in and the fidelity of the handling qualities evaluation. The inclusion of auxiliary tasks in an evaluation task will depend upon the program objective, but may not be required for handling qualities studies in which the control task is of primary interest. Additional workload imposed by the auxiliary tasks can actually interfere with the pilot's evaluation of the characteristics of greatest interest but, of course, must ultimately be taken into account.

No hard and fast rule can be given for defining the evaluation task because it is obvious that the program objectives will play a significant part, but the nearer the selected task represents all the demands of the real mission during the flight phase or subphase being evaluated, the less will be the extrapolation required of the pilot.

For pilot ratings that apply to a complete flight, flight phase, or subphase, the rating must consider all disturbances specified for the mission in the sense of being required operations. Thus, more extrapolation is expected for these ratings, placing greater reliance on the pilot's judgement than for either task or composite ratings. On the other hand, task and composite ratings must be reviewed with caution, as they may not include the most critical conditions and, therefore, could be misleading.

The selection of a complete flight, flight phase, or subphase as the unit to be rated will therefore depend upon the program objective, the characteristics of primary interest, and the degree to which it is desired to draw upon the pilot's training, experience, and knowledge to assess and extrapolate beyond the specific task provided. Several aspects of task selection involved in actual practice are discussed further in the following paragraphs.

Task vs. flight phase or composite ratings.- To provide a rating based on the simulated task is, of course, the most direct approach and reduces the uncertainties of asking the pilot for extrapolation. It is weak, however, in that the task selected may not represent critical flight conditions, thereby allowing a nonconservative leniency in the interpretation of the pilot rating. Obviously, the pilot will not be as influenced by mission objectives if he is told to confine his rating to the evaluation task, although it may be difficult for him to exclude considerations that he knows he would consider under actual operating conditions. If, however, all the separate tasks or subphases needed to define a flight phase can be provided, separate ratings may be obtained for each task or subphase, and a composite rating then given for the multiple tasks or subphases required to represent a flight phase. Providing all the separate tasks required to define a flight phase, however, is seldom possible even by simulation. Nor is it always possible in actual flight, although its importance may dictate flying to remote areas to find environmental conditions for the actual tests.

If it is then not possible to provide all the separate tasks required to define a given flight phase, it may be desirable to base a flight phase rating largely on the pilot's ability to draw on his knowledge, experience, and use of pilot-induced disturbances or self-induced tasks. Such a procedure utilizes the maximum capability of the pilot but also introduces extrapolation, with the inherent risk of his occasionally overlooking a potential problem or of being unduly critical of certain characteristics. The extent to which the pilot is expected to compensate for limitations in the simulated situation must be clearly understood at the start of a program.

If the time factor and probability of occurrence are the same for each task, the composite rating will likely reflect the most critical task. If the probability of occurrence is low for one of the tasks (as might be attributable to severe turbulence), it is still possible for the probability of encounter to influence a composite rating in an undefined manner unless such a task is excluded from the composite rating. The experimenter must decide whether composite ratings, which include "probability of failure" or probability of encountering "unusual" environmental conditions, are to be assessed by the pilot or someone else. There must be no doubt as to whose responsibility this is, however.

Transient disturbances.- When a steady-state failure is designated, the pilot is exempt from considering the probability of a failure. However, someone must consider the probability of encountering transient disturbances from engine or other failures, wind shear or other short-term environmental conditions. In these cases, the pilot might have to consider the duration of the disturbance as well as its level. If specified in the mission definition, the pilot must consider disturbances whether they are provided in the task or not.

Admittedly, a rating that reflects extrapolation for the effect of an undefined level and extent of a disturbance represents an approximation, but this may often be preferable to ignoring the disturbance.

The effect of certain disturbances, such as those induced by the environment and the dynamics of failure, on pilot rating will depend heavily upon the aircraft state. As a rule, transient disturbances from whatever source will affect the pilot rating less if the handling qualities are good rather than poor. For this reason, it becomes increasingly important to provide more accurate dynamic representation of transient disturbances as handling qualities deteriorate.

Single axis or single parameter evaluations.- Confusion can occur when ratings are requested for specific parameters or for a single axis rather than for the complete pilot-vehicle combination in performance of its mission. It should be *handling qualities* that are rated, with the influence of specific parameters identified through changes, if any, in the pilot ratings and from the pilot comment data.

Single-axis simulations can be of considerable value in quick look evaluations but should be clearly identified, so that the limitations of the data can be recognized. The task that, for example, includes freedom for maneuvering in pitch only cannot provide information on either total pilot workload or control coupling. When a single axis or single parameter is of primary interest, it is preferable to incorporate the single axis characteristics into a full multiple-axis (six degrees of freedom) task so that the evaluation can be made in the full context of handling qualities.

Deficiencies evaluated in the longitudinal flight mode cannot be simply added to deficiencies evaluated separately in the lateral-directional mode. As a consequence, the most critical single axis task cannot necessarily be assumed to be the most critical overall pilot-vehicle task.

A parallel situation arises in the general application of quantitative criteria for handling qualities. As a rule, such criteria are developed for specific parameters with all other parameters at a satisfactory level. Such is not necessarily the case in real life, so that one cannot expect to find single parameter criteria that apply accurately to all aircraft with their various roles, configurations, and operating environments.

Preoccupation with variations in a single parameter should not be allowed to distract the pilot from the fact that his ratings apply to handling qualities as a whole, for the task (or flight phase) in context of the aircraft role. Assessment of single parameters or single axis effects can be very helpful to a designer, but special care must be taken in the development and presentation of such data. Programs of such limited scope are likely to introduce considerable pilot extrapolation with a resulting low level of confidence so that in some cases it may be more desirable to obtain only pilot comment data or comparative results not associated with a handling qualities rating.

An evaluation may often involve comparisons or relative assessment of specific characteristics, but the evaluation pilot should not become so engrossed in comparisons that he loses sight of the absolute aspects of performance and workload in the context of the role and mission requirements. The use of an entirely separate rating scale, specifically for relative assessment of individual stability and control parameters, has been considered but abandoned because of possible confusion introduced by a second scale.

Pilot Assessment Considerations

Pilot rating.- As a shorthand representation of the handling qualities of an aircraft in the performance of a defined mission and task, a pilot rating will be meaningful only in proportion to the care taken in developing the program (defining objectives, the role and mission, the evaluation task, what the rating applies to, the simulation situation and extent of pilot extrapolation involved). Unless a common basis is established and any criteria used are clearly indicated, one cannot expect to achieve reliable data and comparable ratings among pilots. Large disagreement between pilot ratings is usually traced to incomplete program development.

There tends to be some disagreement among pilots as to how they actually arrive at a specific numerical rating. Some pilots lean heavily on the specific rating description and look for the description that best fits their overall assessment. Other pilots prefer to make the dichotomous decisions sequentially, thereby arriving at a choice between two or three ratings. The decision among the two or three ratings is then based upon the adjective description. In concept, the latter technique is preferable since it emphasizes the relationship of all quality decisions to the aircraft role and mission requirements. With the final version of the revised scale, the pilot decisions shown *must* be considered in order to define the category boundaries.

The actual technique used is probably somewhere between the two techniques discussed above and is not so different among pilots. In the past, the pilot's choice has probably been strongly influenced by the relative usefulness of the descriptions provided for the categories on one hand, and the numerical ratings on the other. The evaluation pilot is more or less continuously considering the rating decision process during his evaluation. He proceeds through the dichotomous decisions to the adjective descriptors enough times that his final decision is a blend of both techniques.

Half ratings (e.g., rating 4-1/2) generally indicate reluctance of the evaluation pilot to assign either of the adjacent ratings to describe the configuration. Any finer breakdown than half ratings is hardly ever justified since any number greater than or less than the half rating implies that it belongs in the adjacent group. Any distinction between configurations assigned the same rating must be made in the pilot comments. Use of the 3-1/2, 6-1/2, and 9-1/2 ratings is discouraged because they represent important "boundary" conditions and the decision as to which category is selected may be significant even though hard to make.

As a general rule, pilot ratings and comments are preferably given on the spot when the characteristics, performance, and workload are fresh in mind. If the pilot should later want to change his rating, the reasons for the change may be of interest. In some cases, an attempt should be made to repeat the configuration later in the evaluation program.

Pilots' comments.- The use of a rating scale considered for universal handling qualities application leads to the assumption that the numerical pilot rating can represent the entire qualitative assessment. Extreme care must be taken against this oversimplification because the numerical ratings do not constitute the complete results of the data gathering process.

As one might expect, the evaluation data most often neglected are the pilots' comments, either because they are not recorded or because they are often difficult to deal with because of their qualitative form, and perhaps their bulk. Often the nature of the experiment allows the pilot neither the time nor the opportunity to identify the cause of his objections. Ratings, without the pilot's objections, are only part of the story. Only if the deficient areas can be identified, can one expect to devise improvements to eliminate or attenuate the shortcomings. The pilot comments are the means by which the identification can be made.

The pilots' objections to the handling qualities are important therefore to the airplane designer who is responsible for improving the handling qualities and to the engineer who is attempting to understand and use the pilot rating data. If ratings are the only output, the engineer has no real way of assessing whether the objectives of the experiment were actually realized. A pilot's comments supply a means of assessing whether his objections (which lead to his summary rating) were related to the mission, to some extraneous factor in the execution of the experiment, or to his inaccurate interpretation of various aspects of the mission. For pilots' comments to be most useful, several details must be kept in mind.

Generally, pilots should comment in the simplest possible language. Attempts to translate the observed characteristics or responses into engineering terms should be avoided, unless such terms accurately supplement the pilot's observations given in descriptive terms. The pilot should report what he sees and feels, and describe his difficulties in carrying out whatever he is attempting. It is then important for the pilot to relate his difficulties in executing specific tasks to their effect on the accomplishment of the required operations.

The pilot should be encouraged to make specific comments when evaluating each configuration. These comments generally are in response to questions developed during discussions of the mission and simulation situation. The pilot must also be encouraged to comment regarding his difficulties over and above the answers to the specific questions asked of him. In this regard, the test pilot should strive for a balance between a continuous running commentary and only occasional comment in the form of an explicit adjective. The former often requires so much editing to find the substance that it is often ignored, while the latter may add nothing to the numerical rating itself.

The pilot's comments must be collected during or immediately after each evaluation. If the comments are left until the conclusion of the evaluation, they are often forgotten. For both in-flight and ground simulator evaluations, this means that provision should be made for wire or tape recording. The immediate recording of key words or phrases on a kneepad can often be easily expanded to the full content after the task or evaluation is completed. It has been the experience of the authors that the best voluntary comments are often given during the evaluation. A useful procedure is to encourage voluntary comment and note-taking during the evaluation and to require answers to specific questions in the summary comments at the end of the evaluation.

Questionnaires or explicit check lists ensure that: (a) all important or suspected aspects are considered and not overlooked, (b) the reason for a given rating is specified, (c) an understanding is provided of the tradeoffs with which pilots must continually contend, and (d) supplementary comment that

Description	Numeral*
No tendency for pilot to induce undesirable motions.	1
Undesirable motions tend to occur when pilot initiates abrupt maneuvers or attempts tight control. These motions can be prevented or eliminated by pilot techniques.	2
Undesirable motions easily induced when pilot initiates abrupt maneuvers or attempts tight control. These motions can be prevented or eliminated but only at sacrifice to task performance or through considerable pilot attention and effort.	3
Oscillations tend to develop when pilot initiates abrupt maneuvers or attempts tight control. Pilot must reduce gain or abandon task to recover.	4
Divergent oscillations tend to develop when pilot initiates abrupt maneuvers or attempts tight control. Pilot must open loop by releasing or freezing the stick.	5
Disturbance or normal pilot control may cause divergent oscillation. Pilot must open control loop by releasing or freezing the stick.	6

*These numerals are not related to the pilot rating scale.

Figure 8.- Classification of PIO tendency.

might not be offered otherwise is stimulated. It is recommended that the pilots participate in the preparation of the questionnaires. The questionnaires should be modified if necessary as a result of the pilots' initial evaluations. On occasion, it may be desirable to classify pilots' comments by having the pilots select one of several ranked comments about a specific characteristic. An example of such a classification of specific pilots' comments is shown in figure 8 for PIO tendency. Classification as shown in this example is for easy identification only, and is not to be confused with the designation for pilot rating.

Simulation Situation

A pilot evaluation is seldom conducted under the full circumstances of an actual flight. It almost always involves simulation to some degree because of the absence of the real situation. As an example, the evaluation of a day fighter is seldom carried out under the circumstances of a combat mission where the pilot is not only shooting at real targets but is being shot at with real bullets. Therefore, after the program has been defined and the decision made as to what is being rated, the relationship of the simulation to the real situation must be explicitly stated for both the engineer and the evaluation pilot so that each may clearly understand the limitations with respect to what is provided in the task, the environmental disturbances, the cockpit interface, and the completeness of the simulation of the stability and control characteristics.

The pilot and engineer must know not only what is left out of an evaluation program, but also what is in that should not be in. The fact that the anxiety and tenseness of the real situation are missing, and that the airplane is flying in the clear blue of calm daylight air instead of in the icy, cloudy, turbulent, darkness of the real mission could affect the results and should be considered during the program development and the interpretation of the results.

Cockpit interface.- The cockpit interface must be specified, at least to the extent necessary to identify any factors that influence handling qualities. As a rule, once this is done for a given program it remains fixed and is merely reference information. When stability and control characteristics, for example, are the primary interest, features pertaining to the flow of information to and from the cockpit probably would not be considered as variables in the study, but they must be noted with sufficient detail to establish at least any possible qualitative influence on the results.

The individual cockpit features, such as control system characteristics and instrument display, may, however, often include the specific variables to be studied. In some cases, these variables will be made known to the evaluation pilot, while in others, it will be more important that he assess only the overall handling qualities with respect to task accomplishment.

Unless control system characteristics are a variable to be studied, it is desirable to provide an accurate representation of the anticipated vehicle control system. Such factors as control system break-out force, friction, inertial characteristics, or system gearing and sensitivity may significantly affect pilot rating. If it is not practical to represent the vehicle control system characteristics accurately then system characteristics should be provided that are at least satisfactory to the evaluation pilots and do not introduce unwanted problems. It is often desirable to allow evaluation pilots to establish comfortable levels of control sensitivity, for example, before beginning an evaluation program. This procedure has distinct advantages in reducing the number of uncontrolled variables that may enter into an evaluation program. Care must be taken, however, that this procedure is not used when the control sensitivity is a variable.

Repositioning any of the selectors available to the flight crew to change aircraft configuration will depend on the flight phase or task being evaluated. Visual information available to the pilot is defined by such features as the cockpit cut-off angle, the simulator system for providing external information, and the types and locations of the cockpit instruments.

Aircraft environment.- The extent to which aircraft environmental factors are included in the simulation must be described. It is important that the level of such disturbances be related to the length of time they are to be coped with. This is usually for the duration of a flight phase, or specified task, but if it is to be considered as a transient condition, this should be noted.

Should the evaluation be conducted under actual flight conditions, it may be desirable to secure a turbulence classification based on the standardized scale from the FAA Airman's Information Manual (fig. 9), or to relate to other documentation as may be available.

The probability of occurrence of various levels of turbulence is an important consideration, but is much too complex for the pilot to consider during an evaluation.

The influence of environmental disturbances varies inversely with the level of handling qualities; that is, in general, the poorer the handling qualities, the more they are influenced by adverse disturbances. There is no simple rule, however, for translating ratings obtained in smooth air to ratings applicable to rough air.

Environmental disturbances with some undefined probability of occurrence can strongly influence the aircraft design and its handling qualities. For this reason, their inclusion can be essential to the conduct of handling qualities experiments. When no provision is made for actual or simulated

Intensity	Aircraft reaction	Reaction inside aircraft	Reporting term	Definition
LIGHT	Turbulence that momentarily causes slight changes in aircraft attitude, altitude, or heading. Report as Light Turbulence; OR Turbulence (light bumpiness) that causes slight aircraft fluctuations at rapid intervals without appreciable change in altitude, roll, or yaw. Report as Light Chop.	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects remain at rest, food service may be conducted, and little or no difficulty is encountered in walking.	Occasional Intermittent Continuous	Less than 1/3 of the time 1/3 to 2/3 More than 2/3
MODERATE	Turbulence that is similar to Light Turbulence but of greater intensity. Changes in aircraft attitude, altitude, or heading occur, but the aircraft remains in positive control at all times. Report as Moderate Turbulence. OR Turbulence that is similar to Light Chop but of greater intensity. It causes rapid bumps or jolts without appreciable change in aircraft altitude, roll, or yaw. Report as Moderate Chop.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.	NOTE 1. Pilots should report location(s), time, intensity, altitude, type of aircraft and, when applicable, duration of turbulence. 2. Duration may be based on time between two locations or over a single location. All locations should be readily identifiable. EXAMPLES a. Over Omaha, 1232Z, moderate turbulence, Flight Level 300, B707 b. From 50 miles south of Albuquerque to 30 miles north of Phoenix, 1235Z to 1250Z, occasional Moderate Chop, Flight Level 320, DC-8	
SEVERE	Turbulence that causes large changes in aircraft altitude, attitude, or heading. It may cause large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as Severe Turbulence.	Occupants are forced violently and repeatedly against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.		
EXTREME	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as Extreme Turbulence.			

Figure 9.- Turbulence criteria.

environmental disturbances, it may be necessary for the pilot to learn their effect on handling qualities by employing self-imposed disturbances. Such procedures have limited application in a sophisticated simulation program, but do have considerable value in "short look" programs.

Pilot stress.- Surprise and stress can interfere with the pilot's performance by distracting him from the primary task. Considering these factors in depth is usually left to the more sophisticated programs, but those elements that contribute to greater fidelity and realism in a simulation program will be found desirable. The sharp jolt of the cockpit when a bad landing occurs contrasts vividly with the smooth conditions of a good landing.

An element of surprise and stress should be introduced when the dynamic effects of control system or SAS failures are being evaluated. To be truly objective would require data from many occurrences introduced in a random manner during the time the pilot is engrossed in the performance of a task.

If surprise and stress are not included in the task, the evaluation pilot must simulate surprise, distraction, or unattended operation by using a delayed reaction time. The stress or rapid increase in pilot workload when two or more adverse conditions or situations occur together can be studied in more sophisticated simulation programs. These potential "operating problems" consisting of combinations of failures or weather conditions are apt to raise the question of probability of occurrence. Again, this question should be separated from the pilot assessment whenever possible. The pilot rating should reflect the difficulty and effect on performance of the occurrence relative to successful completion of the task or flight phase under evaluation.

Therefore, such occurrences must originate with the program objective and be documented in the test plan as to how they will be executed; that is, whether they will be included in a task or left to the pilot's individual assessment.

Pilot extrapolation and confidence.- The question of simulation enters into nearly every evaluation program to some degree. Previous studies (ref. 9) have shown that sophistication is not necessarily the key to simulator usefulness although it can extend the range of application. Deciding "what a pilot rating applies to" (specific task or flight phase), and the completeness of the simulation will determine the degree to which pilot extrapolation is to be relied on. Neither the pilot nor the engineer retains confidence in the results if the need for extrapolation of observed results becomes too great. Guidelines have been drawn in this report to guard against this problem while at the same time encouraging full utilization of the trained and experienced test pilot.

It is felt that careful planning and agreement on program objectives, mission definition, what is being rated, and the execution of the experiment can limit the uncertainties of extrapolation.

In order to provide a means for expression, on the part of pilots in particular, a *confidence factor* could be introduced into programs in which simulation is involved. A definition might be "the ratio of the information available (to the pilot) in the simulation situation to the information required to derive a realistic pilot rating." While provision is made for the use of such a confidence factor, no recommendation as to its use is given in this report. If used, care must be taken to insure that the confidence factor does not inhibit or otherwise confuse the actual pilot ratings assigned. As reference information, a confidence factor could help a pilot focus his comments on the adequacy of the simulation, but questionnaires could serve the same purpose.

- CLASS A

  A pilot may usually assign a rating with a relatively high degree of confidence, although be may have mild reservations because of incomplete or inadequate simulation of motion cues, disturbances, visual information, or other factors affecting pilot workload.

  Supplementary tasks, if needed, can be adequately provided by the pilot.

- CLASS B

  A pilot can assign a rating with only a moderate level of confidence because of uncertainties introduced by a lack of representative environmental disturbances as well as incomplete or inadequate simulation of motion cues, disturbances, visual information, or other factors affecting pilot workload.

  Supplementary tasks may be desired, but are not available.

- CLASS C

  A pilot can assign a rating with only minimum confidence because considerable pilot extrapolation is required due to an incomplete task, thereby requiring considerable reliance on self-imposed tasks and maneuvers for assessment.

  This may also be aggravated by incomplete or very limited simulations of motion cues, disturbances, visual information, or other factors affecting pilot workload.

Figure 10.- Classification of pilot confidence factor.

For those who favor using a confidence factor, a simple classification is proposed in figure 10, as A, B, or C. Studies involving "quick look" or rudimentary simulation may often call for pilot ratings in which the pilot is confident in only a relative rather than an absolute sense. For these, a "C" classification might be appropriate. An attempt should be made to place all other evaluations in Class A, thereby allowing Class B to be used only when a pilot has difficulty deciding between A and C.

The Briefing Guide

In order to summarize the content of this report in a form which may be applied directly to the execution of handling qualities experiments, a "Briefing Guide" has been assembled in appendix B. The purpose of this guide is to outline a format to insure that all pertinent documentation is covered for each evaluation program. Only in this way can the evaluation pilots be sure that everyone is talking about the same thing. Subsequent analysis of the data, reporting, and ultimate comparison with data from other sources is then materially aided.

The briefing guide enables the pilot and engineer to know what is missing from an evaluation program, as well as what is provided.

Once the information is tabulated, it should be apparent just what is being evaluated and rated, what the task is, the conditions under which the evaluation is performed, and the applicability of the data. With the important information provided in a Briefing Guide, it should be possible to evaluate handling qualities more effectively and to improve communication not only between pilots and engineers, but between various research and development groups as well.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif. 94035, Nov. 13, 1968
125-19-06-06-00-21

APPENDIX A

DEFINITIONS

COMPENSATION - The measure of additional pilot effort and attention required to maintain a given level of performance in the face of deficient vehicle characteristics.

CONFIGURATION - The aircraft geometry as established by the actual position of movable portions and surfaces controllable by the selectors, and the state of operability of on-board systems.

Examples: Auto-throttle on, flaps at 15°, wing sweep at 45°, etc.

COCKPIT INTERFACE - The means provided for the flow of information to and from the pilot. These include the display of information available to the pilot as well as the type and characteristics of the cockpit controls.

Examples: Description of cockpit instruments and layout. Description of control system (i.e., stick, wheel, force - deflection gradients, sensitivities, primary, secondary controls, and selectors provided).

CONTROLS - A distinction is made between the types of controls in the cockpit according to their function. Principal controls are the primary and secondary controls.

Primary - Those controls used by a pilot to continuously modify the movement of the aircraft.

Examples: Pitch, roll, yaw controls, throttle, DLC.

Secondary - Those controls used by a pilot to make discrete changes in the movement or balance of the aircraft, thereby modifying the need for actuation of the primary controls.

Examples: Pitch, roll, and yaw trimmers, aerodynamic braking devices.

Selectors - Those cockpit controls available to the crew for changing aircraft configuration.

Examples: Flaps, slats, wing sweep, BLC.

FAILURE STATE - A steady-state failure characterized by the various failed systems that affect the handling qualities. The dynamic effect of a failure is called a change of state and should be noted separately.

Examples: Any failure resulting in loss of selected function. Engine failure, augmentation system, failure in stability, autothrottle, primary flight control system (power boost, electric stick, servo control feel, etc.) or secondary flight control system (trim, aerodynamic brake, etc.).

FLIGHT or SORTIE - A complete sequence of flight phases of an aircraft within one of its roles. Full or complete mission.

Example: The composite of takeoff, climb, cruise, combat (or other special phase), descent, approach, landing.

FLIGHT PHASE - A designated portion or segment of a complete flight. A mission phase. A flight phase may be represented by one or more separate tasks.

Examples: (a) Common phases - takeoff, climb, cruise, descent, approach, and landing.

(b) Special phases required by role - formation, refueling, air-to-air or air-to-ground combat, weapon delivery, emergency conditions (i.e., 2- or 3-engine operation, emergency descent, etc.), VTOL transition, VTOL hover, STOL takeoff, and STOL approach.

FLIGHT SUBPHASE - That part of a flight phase having a single objective, and a single configuration or change in a configuration.

Examples: Air-to-air tracking, terminal area holding, glide slope capture, localizer capture, ILS tracking, wave-off.

HANDLING QUALITIES - Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role.

MANEUVER - A planned and regulated movement of an aircraft for the purpose of aiding the completion of a given control task.

Examples: Bank, turn, dive, pullup, turn reversal, roll reversal, rolling pullup, steady sideslip, return from sideslip, control steps and pulses, maintenance of a steady condition.

MISSION - The composite of pilot-vehicle functions that must be performed to fulfill operational requirements. May be specified for a role, complete flight, flight phase, or flight subphase.

PERFORMANCE - The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task. (Pilot-vehicle performance is a measure of handling performance. Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task.)

ROLE - The function or purpose that defines the primary use of an aircraft.

SPECIAL CONDITIONS - The special circumstances pertinent to the evaluation (i.e., aircraft environment and pilot stress).

Examples: Special conditions of weather and environment, turbulence, wind shear, ceiling, visibility - night, etc. Pilot awareness, surprise, or distraction with respect to impending failure or disturbances.

STATE - The mass distribution and failure situation that determine completely the behavior characteristics of the aircraft. A state without a failure is a normal state.

TASK - The actual work assigned a pilot to be performed in completion of or as representative of a designated flight segment.

Control - That part of a task which requires continuing actuation of the principal controls and use of the selectors (see "CONTROLS") as required.

Examples: Movement between specified points, tracking part of weapon delivery, ILS or VOR tracking.

Auxiliary - That part of a task which involves the pilot in actions other than direct control of the aircraft.

Examples: Navigation, communication monitoring, and selection of systems.

WORKLOAD - The integrated physical and mental effort required to perform a specified piloting task.

Physical - The effort expended by the pilot in moving or imposing forces on the controls during a specified piloting task.

Mental - Mental workload is at present not amenable to quantitative analysis by other than pilot evaluation, or indirect methods using physical workload (input) and the task performance measurements. An example would be the improvement associated with flight-director type displays which reduce the mental compensation normally required of the pilot.

APPENDIX B

BRIEFING GUIDE AND RATING INFORMATION FOR HANDLING QUALITIES EXPERIMENTS

PROGRAM DEFINITION

Objectives

General:

Research ☐ Development ☐ Acceptance ☐ Other ☐

Aircraft role ______________________________

Flight segment of interest ______________________________

Parameter or variable of primary interest ______________________________

Mission description:

General statement of the required operations for the flight segment of interest in context of aircraft role.

1. What is pilot-vehicle combination required to accomplish?

____

____

____

____

____

____

2. What are the conditions under which these required operations are to be carried out (i.e., aircraft state, environment, and cockpit interface)?

____

____

____

____

____

Scope

Short look (guide to further tests) ☐

Long look (definitive as possible) ☐

Task related only (minimize pilot extrapolation) ☐

Mission or flight segment related (pilot extrapolation encouraged) ☐

Nature of task or tasks provided: ☐

Short term ☐ Long term ☐

Critical task(s) included? ☐ Or left for pilot extrapolation? ☐

Identify: ______________________________

____

____

Are simulated disturbances provided or to be supplied by pilot?

____

Use of pilot-initiated or self-imposed tasks, disturbances, or short-term maneuvers.

____

____

Provision for familiarization: ______________________________

____

Measured performance:

Is performance to be measured? ______________________________

Pilot-vehicle (output) ☐ ______________________________

____

Pilot workload (input) ☐ ______________________________

Other measurements? ☐ ______________________________

Additional provisions: ______________________________

____

Are additional runs allowed for evaluation?__________. Explain:

____

____

RATING INFORMATION

What is to be rated?

☐ Handling qualities ☐ Other ______________________________

☐ Task ____

☐ Flight segment (flight phase or subphase) ____________________

☐ Composite of tasks (specify tasks included in composite rating)

____

☐ Composite of subphases (specify subphases) ____________________

What is provided?

Test vehicle: (aircraft, spacecraft, simulator, etc.) ______________

____

Aircraft state:

Normal ☐ Emergency ☐ Identify failure: ____________________

____

Configuration: ____

____

Gross weight: ____

Mass distribution: ____

Changes in aircraft state:

Configuration changes (during task or designated phase) __________

____

____

Transient failures (unanticipated failures to be introduced into task for pilot reaction to and correction of resulting disturbance)

____

Cockpit interface:

(Brief description of important items noting unusual or detracting or limiting characteristics in particular)

____

Principal controls:

Primary controls: ____

____

____

____

Secondary controls: ____

____

____

Selectors: ____

Cues and disturbances provided: _______________________________

____

Motion: ____

____

____

Visual:

Instruments: Conventional ☐ Novel ☐

Full panel ☐ Part panel ☐

(Brief statement of instruments or characteristics which may affect the evaluation)

____

____

External vision:

External visual display VFR provided ☐ not provided ☐

IFR only ☐

(Brief description of information provided)

____

____

____

____

____

____

Task(s):

Control task description: ______________________

____

____

____

____

____

Auxiliary tasks? Yes ☐ No ☐

Aircraft environment:

Day ☐ Night ☐

Visibility conditions: ______________________

____

Turbulence ☐ ______________________

Wind shear ☐ ______________________

Crosswind ☐ ______________________

Other weather conditions: ______________________

PILOT EVALUATION DATA

Form of results

Pilot rating ☐ Comments ☐ Questionnaire ☐ Oral debriefing ☐

Other ☐ ______________________________

____

Pilot rating scale: ______________________________

Principal items for comment: ______________________________

____

Program assessment:

(Comments and recommendations on validity, effectiveness, etc.
Confidence factor - if used)

____

____

APPENDIX B - Example 1

BRIEFING GUIDE AND RATING INFORMATION FOR HANDLING QUALITIES EXPERIMENTS

PROGRAM DEFINITION

Objectives

General:

Research ☐ Development ☒ Acceptance ☐ Other ☐

Aircraft role *Commercial transport*

Flight segment of interest *Landing approach*

Parameter or variable of primary interest *Longitudinal stability*

Mission description:

General statement of the required operations for the flight segment of interest in context of aircraft role.

1. What is pilot-vehicle combination required to accomplish?

Conduct VFR and IFR approaches and landings, either Day or Night, with an accuracy ±50 ft from desired path and ±5 k airspeed. Ninety percent consistency is allowable if pilot can execute wave off safely or make an acceptable landing. (5 ft/sec at touchdown, within 50 ft of centerline, with side velocity less than 5ft/sec)

2. What are the conditions under which these required operations are to be carried out (i.e., aircraft state, environment, and cockpit interface)?

Both normal and emergency state with pitch SAS failed. Approach configuration, Light-Moderate turbulence, Night or Day, 0-20 k crosswind, 10 k per 100 ft windshear. Cockpit interface items must not be considered limiting or to introduce significantly objectionable characteristics to the evaluation pilots.

Scope

Short look (guide to further tests) ☐

Long look (definitive as possible) ☒

Task related only (minimize pilot extrapolation) ☐

Mission or flight segment related (pilot extrapolation encouraged) ☒

Nature of task or tasks provided:

Short term ☐ Long term ☒

Critical task(s) included? ☐ Or left for pilot extrapolation? ☒

Identify: *Consider effect of higher level of turbulence on instrument approach.*

Are simulated disturbances provided or to be supplied by pilot?

Light turbulence and wind shear provided.

Use of pilot-initiated or self-imposed tasks, disturbances, or short-term maneuvers.

During familiarization runs only.

Provision for familiarization: *Five runs at beginning of each session.*

Measured performance:

Is performance to be measured? *Yes*

Pilot-vehicle (output) ☒ *ILS tracking error*

Pilot workload (input) ☒ *Control column and throttle activity (reversals and work)*

Other measurements? ☒ *Altitude and airspeed error*

Additional provisions: *All but familiarization runs used only to verify learning curve.*

Are additional runs allowed for evaluation? *Yes*. Explain:

Pilot may make nonperformance evaluation runs as time allows after completion of all data runs.

RATING INFORMATION

What is to be rated?

- [X] Handling qualities [ ] Other ______
- [ ] Task ______
- [X] Flight segment (flight phase or subphase) *Landing approach*
- [ ] Composite of tasks (specify tasks included in composite rating) ______

Composite of subphases (specify subphases) ______

What is provided?

Test vehicle: (aircraft, spacecraft, simulator, etc.) *S-16 Moving Base Simulator*

Aircraft state:

Normal [ ] Emergency [X] Identify failure: *Pitch SAS failed.*

Configuration: *Approach configuration, gear ↓, flap ↓ 40°, leading edge extended, wing sweep 20°, etc.*

Gross weight: *Maximum landing weight*

Mass distribution: *C.G. at aft limit*

Changes in aircraft state:

Configuration changes (during task or designated phase) *Flap deflection increased from maneuver to approach upon intercepting glide slope.*

Transient failures (unanticipated failures to be introduced into task for pilot reaction to and correction of resulting disturbance)

Pitch SAS failure to be introduced unexpectedly on two SAS on runs.

Cockpit interface:

(Brief description of important items noting unusual or detracting or limiting characteristics in particular)

Principal controls:

Primary controls: *Conventional wheel and yoke with 707 feel characteristics; single-throttle control for all engines.*

Secondary controls: *Electric trim switch on wheel for pitch and roll, yaw trim - not provided; spoiler actuation not provided in cockpit, but available on voice command.*

Selectors:

Cues and disturbances provided: *Pitch and roll cues with turbulence in vertical motion.*

Motion:

Visual:

Instruments: Conventional ☒ Novel ☐

Full panel ☐ Part panel ☒

(Brief statement of instruments or characteristics which may affect the evaluation)

External vision:

External visual display VFR provided ☒ not provided ☐

IFR only ☐

(Brief description of information provided)

Closed circuit color T.V. used to provide realistic visual cues 1500 ft to ground accurate 14° vertical (downward) cutoff angle provided, but lateral view restricted to 40° angle. Prominent horizon provided. Fairly good picture resolution enables 3 ft/sec touchdown to be made consistently, but not good enough for much less.

Task(s):

Control task description: *a. Visual approach from crosswind leg, 7000-ft altitude at recommended approach speed to land at 5000-ft elevation. b. IFR-ILS approach, capture and track 3° ILS from OM. No offset crosswind or turbulence 2000 ft RVR. c. Same as b., except with 20-k crosswind, light turbulence, moderate windshear at 100 ft above ground. 2000 ft RVR*

Auxiliary tasks? Yes ☐ No ☒

Aircraft environment:

Day ☒ Night ☒

Visibility conditions: *Test variable*

Turbulence ☒ *Light turbulence*

Wind shear ☒ *10 k per 100 ft (300 ft - 50 ft altitude)*

Crosswind ☒ *20 k*

Other weather conditions: *None*

PILOT EVALUATION DATA

Form of results

Pilot rating [X] Comments [ ] Questionnaire [ ] Oral debriefing [X]

Other [ ] ______________________________

Pilot rating scale: *Cooper-Harper*

Principal items for comment: *Airspeed and flight-path control. Pitch response. Pilot workload.*

Program assessment:

(Comments and recommendations on validity, effectiveness, etc. Confidence factor - if used)

Validity of task. Adequacy of display.

APPENDIX B - Example 2

BRIEFING GUIDE AND RATING INFORMATION FOR HANDLING QUALITIES EXPERIMENTS

PROGRAM DEFINITION

Objectives

General:

Research ☒ Development ☐ Acceptance ☐ Other ☐

Aircraft role *Long-range attack bomber*

Flight segment of interest *In-flight refueling*

Parameter or variable of primary interest *Lateral control*

Mission description:

General statement of the required operations for the flight segment of interest in context of aircraft role.

1. What is pilot-vehicle combination required to accomplish?

By visual references, attain and maintain position relative to tanker within presented bounds for period of 10 min.

2. What are the conditions under which these required operations are to be carried out (i.e., aircraft state, environment, and cockpit interface)?

V = 290 KIAS, h = 30,000 ft, W = initial and refueled. Daytime, smooth air and light turbulence. Straight flight and turn entries.

Scope

Short look (guide to further tests) ☐

Long look (definitive as possible) ☒

Task related only (minimize pilot extrapolation) ☐

Mission or flight segment related (pilot extrapolation encouraged) ☒

Nature of task or tasks provided:

Short term ☐ Long term ☒

Critical task(s) included? ☒ Or left for pilot extrapolation? ☐

Identify: *Success or failure to establish and maintain position with respect to tanker with light turbulence and occassional disturbance of the tanker.*

Are simulated disturbances provided or to be supplied by pilot?

Provided

Use of pilot-initiated or self-imposed tasks, disturbances, or short-term maneuvers.

Only during familiarization or subsequent to notification of test director.

Provision for familiarization: *As desired by pilot.*

Measured performance:

Is performance to be measured? *Yes*

Pilot-vehicle (output) ☒

Pilot workload (input) ☐

Other measurements? ☐

Additional provisions:

Are additional runs allowed for evaluation? *Yes*. Explain:

RATING INFORMATION

What is to be rated?

- [X] Handling qualities   Other *Adequacy of simulation.*
- [ ] Task
- [X] Flight segment (flight phase or subphase) *Special phase - refueling.*
- [ ] Composite of tasks (specify tasks included in composite rating)
- [ ] Composite of subphases (specify subphases)

What is provided?

Test vehicle: (aircraft, spacecraft, simulator, etc.) *Simulator*

Aircraft state:

Normal [X]   Emergency [ ]   Identify failure:

Configuration: *Refueling*

Gross weight: *300,000 and 400,000 lb*

Mass distribution: *Appropriate*

Changes in aircraft state:

Configuration changes (during task or designated phase) *None*

Transient failures (unanticipated failures to be introduced into task for pilot reaction to and correction of resulting disturbance)

Yaw damper

Cockpit interface:

(Brief description of important items noting unusual or detracting or limiting characteristics in particular)

Principal controls:

Primary controls: *Control stick with light control forces, good centering and low friction. Conventional rudder pedals having light forces but objectionably poor centering. Requires pilot adaptation and special consideration.*

Secondary controls: *Trim not provided.*

Selectors: *Not provided - configuration unchanged.*

Cues and disturbances provided:

Motion: *Pitch, roll, and yaw (±45°). Accelerations attenuated by limited translation (±5 ft vertically, ±10 ft laterally; ±10° fore and aft).*

Visual:

Instruments: Conventional ☒ Novel ☐

Full panel ☐ Part panel ☐

(Brief statement of instruments or characteristics which may affect the evaluation)

Considered primarily a visual task. Only primary flight instruments - airspeed, altitude, and rate of climb provided.

External vision:

External visual display VFR provided ☒ not provided ☐

IFR only ☐

(Brief description of information provided)

Closed circuit T.V., enabling visual formation flying with stationary model of tanker aircraft.

Task(s):

Control task description: *(1) Close on tanker, establish contact, maintain hookup for duration of refueling operation without turbulence. (2) Same as (1), except for simulated light turbulence and occasional abrupt displacement of tanker to simulate disconnect.*

Auxiliary tasks? Yes ☐ No ☒

Aircraft environment:

Day ☒ Night ☐

Visibility conditions: *Unobstructed - except for accurate windshield and visibility representation.*

Turbulence ☒ *Light*

Wind shear ☐

Crosswind ☐

Other weather conditions:

PILOT EVALUATION DATA

Form of results

Pilot rating [X] Comments [ ] Questionnaire [X] Oral debriefing [ ]

Other [ ] *Questionnaire will be made available after completion of test.*

Pilot rating scale: *Cooper-Harper*

Principal items for comment: *Pilot workload. Influence of control system characteristics, if any.*

Program assessment:

(Comments and recommendations on validity, effectiveness, etc. Confidence factor - if used)

Realism of task. Adequacy of simulated motion.

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