As a matter of interest, based on tracking scores, pilots currently assigned to fighters almost without exception did better than attack pilots. This would indicate that additional testing might be beneficial to establish whether fighter pilots are a better population from which to select new crews for transitioning into a new multimission aircraft.

DOCUMENTATION

PHASE I

D6-16276
- PART I — SUMMARY (U)
- PART II — COCKPIT/AVIONICS CONFIGURATION AND CREW WORKLOAD EVALUATION (C)
- PART III — PHASE II PLAN, METHODS, AND CRITERIA (U)

D6-16276-1 MISSION ANALYSIS (S)
D6-16276-2 TRAINING ANALYSIS (U)
D6-16276-3 CREW PERFORMANCE COMPUTER MODEL (U)

PHASE II

PART A
D6-60059-1 FINAL REPORT (C)
D6-60059-2 TRAINING REPORT (C)
D6-60059-3 TRAINING APPENDIX (C)
D6-60059-4 AVIONICS SUPPLEMENT (S)

PART B
D6-53563 IFR TEST REPORT (C)

PART C
D6-53564 VFR TEST REPORT (C)
D6-53565 TRAINING MANUAL (U)

STUDY SUMMARY
D6-53575 SIMULATOR TEST SUMMARY (U)

DISTRIBUTION THROUGH MR. Mr. AL CRIM, NASC, WASHINGTON, D.C.

VISUAL SIMULATOR SPECIFICATION REQUIREMENTS AND ACCEPTANCE TESTS

M. ARONSON
Head, Visual Simulation Laboratory
Naval Training Device Center

INTRODUCTION

There was a time in the Naval Training Device Center's history when OFT's (operational flight trainers) were accepted solely on the basis of a number of qualitative flight tests conducted by an NATC Test Pilot and visual simulators were accepted on the basis of a few tests based on good TV receiver testing practice. Since that time we have found out that the OFT is not an aircraft and the visual simulator is not a home TV receiver.

We now try to describe the OFT or the visual simulator in terms which describe what the trainee will see in the visual display and what cues he will get from the displays such as the aircraft instruments, outside environment, etc.

Before we examine the specification requirements themselves, it is important to understand the background leading to the statement of the design parameters. I will first relate the trainee's visual performance to these design parameters, then briefly describe previous visual simulators as examples of inadequate specification coverage and as illustrations of the recommended design parameter coverage I propose. Figure 116 provides a simplified correlation between the trainee's visual performance, the operational situation and possible design parameters of the visual simulator. Some of the visual factors are discussed below, others are discussed in reference (1).

a. Trainee's brightness sensitivity or the operational situation, light level. While the operational situation light level can run from bright daylight (10^5 ft-lamberts) to cloudy night (10^{-4} ft-lamberts), in the visual simulation condition, the eye can work at lower values and smaller ranges because it is very adaptive. The ability of the eye to discriminate light levels is a function of dark (or light) adaptability, contrast ratio, color, size of object, etc. (2).

b. Visual acuity or the smallest object noticed. This is related to the subjective item of detail in the display. Some relationships have been found. Visual acuity increases with background luminance. For example, from (3), Figure 45, for a luminance of .141 millilamberts (.131 foot-lamberts) the visual acuity is 1.0 or 1 minute of arc, while for 100 millilamberts it is 2.2 or .45 minutes of arc. However, form recognition and target identification quickly deteriorate when the target is less than 12 minutes of arc under conditions of reduced viewing time or angular velocity (4). Thus, very small objects, while visible under static conditions, are lost when viewed under flight conditions of navigation, reconnaissance and observation.

c. Temporal discrimination or flashing lights, rotating propeller. This visual capacity has annoyance value and therefore must sometimes be simulated; on the other hand, the visual simulation system can sometimes cause this situation through poor design or malfunction. The main contributor appears to be the rapid change in brightness of the light source or display with time. This has produced symptoms of extreme fatigue, dizziness and even nausea (2).

From a hardware sense, the visual simulator is related to the trainee as shown in Figure 117, showing the principal parts of a Visual Simulation System. The TV chain as one form of information transmission is comprised of the Blocks - Image Generation, Transmission, Projection and Display. Note the interface between the trainee and the display. The second man-machine interface (trainee to vehicle simulator) will not be discussed as it has been covered extensively. While Figure 116 pertained to the Display-to-Man interface only, Figure 117 shows the interrelation between the three blocks of the visual display system as well as the means for closing the loop and providing feedback.

While this Introduction describes the visual simulation system in a general sense it should be realized that a better description of what the visual simulation system should be and do lies in adequately stated specification requirements (Section III of the Military Specification Format) and adequately stated acceptance tests (Section IV of the Military Specification Format).

EXAMPLES OF VISUAL SIMULATORS USING TV SYSTEMS AND THE EXTENT OF DETAIL IN THEIR SPECIFICATIONS.

Some past and current visual simulators are now described to show the variety of simulation approaches used and then the adequacy of description in their specifications is analyzed as a bench mark of what we should not do. These examples cover both training devices and research tools using TV as a data transmission means.

RELATION OF VISUAL VARIABLES TO DESIGN

Operational Situation	Pilot's Visual Performance	Design Parameter
Night time	Brightness sensitivity	Dark adaptation, shape and size of objects, color, contrast
Dim lights, object in sky	Brightness discrimination	Contrast
Color of lights, objects, terrain	Color discrimination	Color of details, lights
Smallest object noticed	Visual Acuity	Size of separation of smallest objects
Distance to target, altitude above ground, distance to runway	Distance judgment	Eye to screen distance, Scale of image, brightness
Recognition of object by shape	Form discrimination	Light level, time of dark adaptability
Relative motion of target, ground speed	Movement discrimination	Position and movement of target with respect to eye
Flashing lights, rotating propeller or rotor blades	Temporal discrimination	Course flicker, critical flicker frequently, duration of flicker

Figure 116.

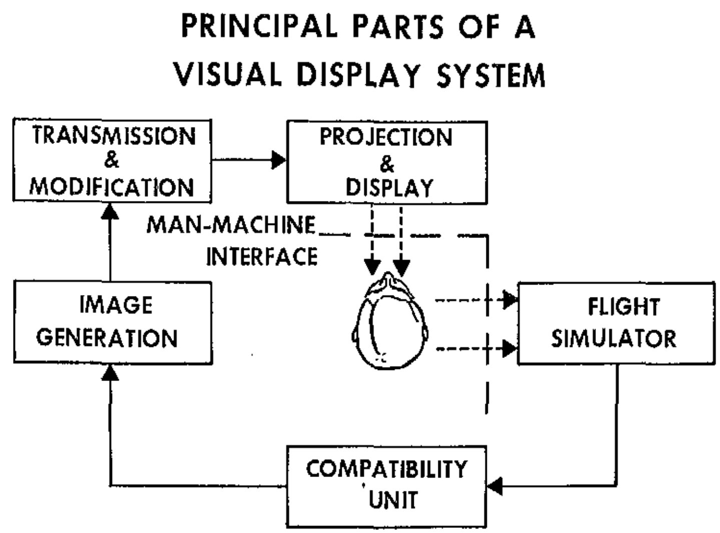

Figure 117.

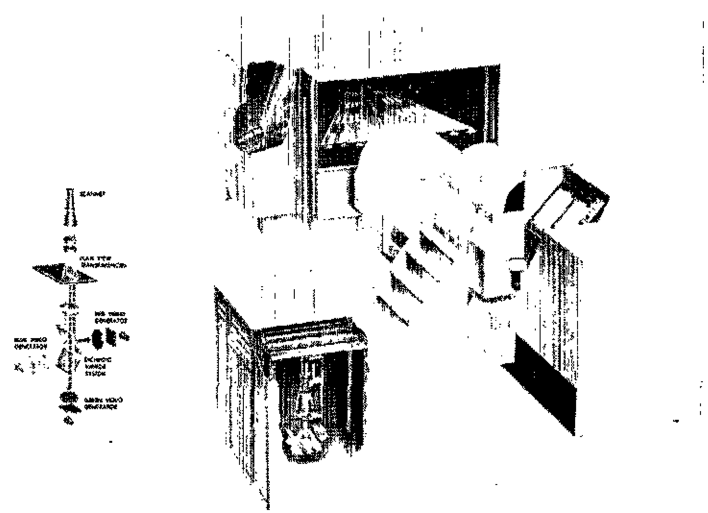

Figure 118. Low Visibility Approach & Landing Attachment For Flight Trainers. Device 2H53.

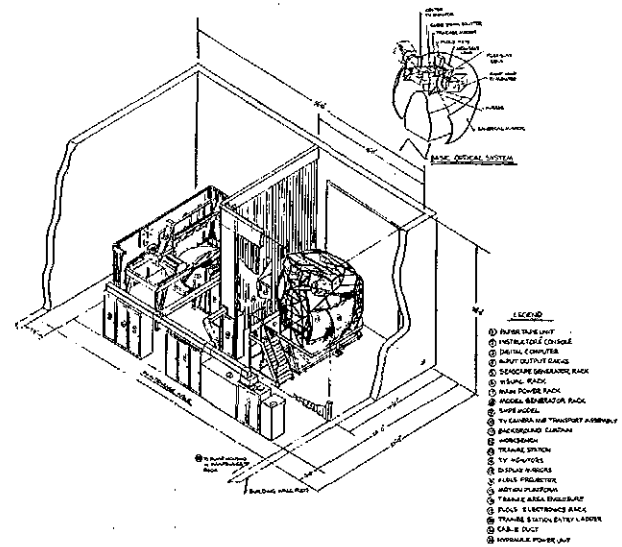

Figure 119. Aircraft Carrier Landing Trainer, Device 2H87.

In the training device field, Figure 118 shows Device 2H53, Low Visibility Approach and Landing Attachment which was designed in 1960 for attachment to various flight trainers. Main features are: Image generation using a 2-D transparency and Flying Spot Scanner, no background. The display consists of a picture generated by a color wheel rear projector falling on a flat screen. A light shield is needed from the display cabinet to the cockpit.

Figure 119 is another trainer example, the current Device 2H87, Aircraft Carrier Landing Trainer. The main features are: Image generation by means of a 3-D Model and TV Camera, background is generated by a transparency and a Flying Spot Scanner. The display is a 3-section reflective virtual image, each 80 degree field of view. The aircraft carrier image can be inserted in any portion of the total 240° field of view.

Now for some examples of research tools. Figure 120 shows the Wide Angle Television System. This system consists of a 3-channel 160° field of view TV Camera, a 3-D Model, and a 3-unit refractive TV projection system with a spherical screen. The camera was developed in 1960 and the projector in 1963. The final example is a new system (Figure 121) currently under development. The image generation subsystem consists of a 3-D Model, a 180° field of view TV camera, a video insetting unit and a 180° field of view Eidophor projector with a spherical screen.

We will now analyze the contents of the specifications which defined the TV systems in some of the above-mentioned devices. How many parameters were cited to define the Visual System? Every statement in the specification which in some way defined the system, device or equipment was listed and counted. As you will see later, each requirement stated in Section III of the Military Specification should be verified by a specific test in Section IV. This should be a stated test, not an implied test to be defined by the Contractor.

The tally is as follows:

Low Visibility Approach and Landing Attachment, Device 2H53, had 16 requirements in Section III and one test requirement in Section IV; that was for a test procedures report, the specific tests were to be defined by the Contractor.

Aircraft Carrier Landing Trainer, Device 2H87, has 17 requirements in Section III and nine test requirements. However, on an initial review of the test procedures report by the Visual Simulation Laboratory, a total of 41 acceptance tests were identified for verifying the design requirements. The final approved test procedures report contains 26 test objectives for the visual system.

The Wide Angle TV projection system of the Ship Handling Visual Display Project had 18 design requirements and one test objective - a test procedures report.

The Wide Angle Lens for TV, using the Eidophor projector, has 15 design requirements in Section III and 8 test objectives/test methods spelled out in Section IV.

As NTDC experience grows so will the number of design requirements in Section III and the number of test objectives required in Section IV of the Specification. The list of requirements to be given results from some hard thinking and testing done at NTDC over the past year and one half - forty-five design requirements and 66 test objectives are enumerated.

GENERAL GUIDELINES FOR INCLUDING DESIGN AND TEST REQUIREMENTS IN THE SPECIFICATION.

What parameters or design requirements should be listed in the TV portion of a device specification which requires a real world visual display, a tactical situation display or a data presentation?

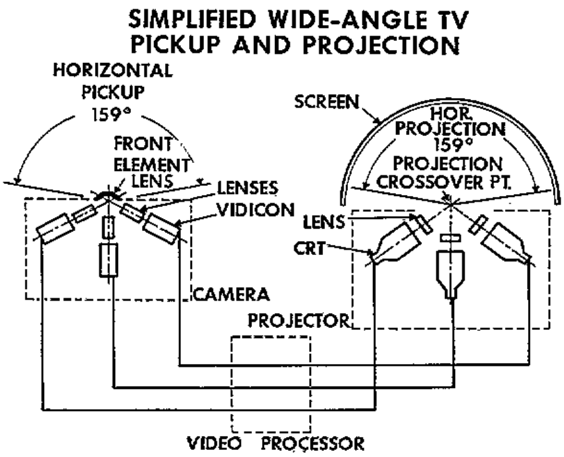

Figure 120.

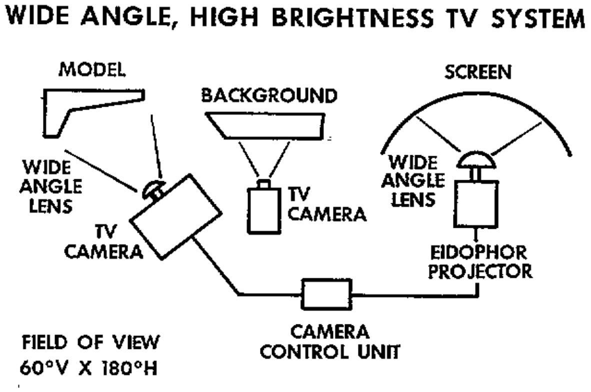

Figure 121.

Let us look at a hypothetical device visual display system which is a composite of several existing subsystems. The components illustrated will follow the designations in the Visual System Block Diagram shown previously. For the Image Generation Block look at the picture of a 3-D Model area and TV camera (Figure 122). Note the scale, light level, coloring range, the field of view, the lens alignment, operating range, etc. These are design parameters to be cited. Another important area is the detail at Instructor's Console and Display Unit. Figure 123, Device 2H53, Instructor's Console will give you an idea of the details to be specified. The adjustment controls, the inputs, the readout, the scoring means, etc.

Figure 122. Harbor Model, Ship Handling Visual Display

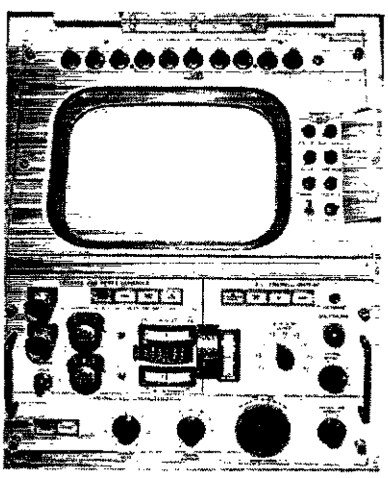

Figure 123. Instructor's Console - Device 2H53.

At this stage let us explore the means for describing each design requirement more closely. First, there is the statement that we want a feature. For example, "the field of view shall correspond to the real world." What is the angle in the real world? For straight in landings it could be 60°, this is the "criteria." Next, how close should this be measured? This is the tolerance, say ± 2.0°. Thus all three items describe a feature fully, the requirement, the criteria and the tolerance. As you will recall the title of this paper addresses itself to the requirements and tests only. The fact that item requirements are listed in this paper does not mean that the necessary criteria and tolerances have been established for each item for every simulation situation. On the other hand, if a requirement is cited in the specification, there should exist a method for testing or measuring that parameter. This test statement then becomes the test objective in Section IV of the Specification. One final permutation of the three factors - A requirement is stated, the criteria is given, a test is defined for measuring it but no tolerance or range of acceptable deviation from the center value exists. This only points to the fact that additional research is required before a perfect specification for a visual simulator can be written.

The order in which the design and performance requirements for a TV visual system should be listed in the specification may be immaterial but they must be in sequence from one end of the system to the other. This aids cross-checking - to say the least. The requirements and test objectives may be grouped in gross areas as shown on Tables 5 and 6. The factors applicable to the components are listed by function - image generation, transmission, display. Then the factors for the entire system are stated.

REQUIREMENT AND TEST FACTORS-COMPONENT

IMAGE GENERATION	DISPLAY AND PROJECTION
MODEL - PHOTOMETRIC	DISPLAY TUBE - ELECTRONIC, PHOTOMETRIC
LENS - OPTICAL	LENS AND SCREEN - OPTICAL, PHOTOMETRIC, SUBJECTIVE
TV CAMERA - PHOTOMETRIC, ELECTRONIC	

TRANSMISSION MEANS (AMPLIFIERS) -	
ELECTRONIC	SUBJECTIVE

Table 5.

REQUIREMENT AND TEST FACTORS

SYSTEM
PHOTOMETRIC
OPTICAL
ELECTRONIC
SUBJECTIVE
DYNAMIC
TEST EQUIPMENT

Table 6.

In the acceptance test area both component and systems tests must be specified. While systems performance can be predicted from component performance, both should be measured to eliminate assumptions. Systems performance tests are required to determine conformance to systems requirements. Component performance is needed, as in OFT testing, to identify the problem areas, as an aid in debugging and to indicate areas for product improvement. In addition it provides a check against the estimated values given in the design report.

NTDC has a research project scheduled to evaluate the Navy Device 2H87 for transfer of training at NAS Pensacola. Analysis of the engineering data and the pilot performance in the simulator versus the aircraft may provide a definition of the perceptual fidelity necessary. (5) The only example of accomplished research in this field is a Goodyear Aircraft Corporation experimental investigation for the Public Health Service in 1966 on the Automobile Driving Simulator. (6) Analysis of the results of this study infer that because of the anomalies in the recorded data and the number of physical factors which uncontrollably varied during the experiments, no quantitative relation could be established between the physical parameters of the display system and the subject's performance obtained for specific tested situations.

As was pointed out previously, a listing of an unqualified requirement, that is, without a specific given value or criterion value has no place in the specification. Research effort is required to establish a criterion and a tolerance value for each of the parameters, presumably for each visual situation to be simulated. Without opening up a new discussion topic, the relation of each specification item to its place in the technical documentation completely defining the visual simulator can best be shown by Figure 124. The factors defining the simulator performance are listed at the left, the customary documents containing and describing the factor are indicated by the "X" or "?". A simple example will show the application of this table. The specification will state:

"The highlight brightness in the center of the visual display (requirement) shall be 2 foot lamberts *(criterion) plus 1 foot lambert minus 0 (tolerance).*" The Design Report will describe in detail how this value is obtained (Proposed Solution). The Specification Test Section could say "measure highlight brightness." (Test Objective). The Test Procedure Report would say: "Position the transparency carriage to sky area. Measure the brightness using a photometer at three points in each display." The resulting reading "2 foot lamberts minimum" would appear in the Test Results Report plus a discussion of the measurements. To carry this example one step more, the results of the transfer of training experiment could be that "at a highlight brightness of 2 foot lamberts, the pilot could align his aircraft on final approach within the same variation that would occur in the aircraft on final approach."

COMPLETE DEFINITION OF A VISUAL SIMULATOR

	NECESSARY TECH DOCUMENTATION			
	SPEC	DESIGN REPORT	TEST PROC. RPT.	TEST REPORT
REQUIREMENT	X	X		
CRITERIA	X	X		
TOLERANCE	X	X		
PROP. SOLUTION	?	X		
TEST OBJECTIVE	X		X	
TEST METHOD	?		X	
TEST EQUIPMENT	?		X	
TEST DATA & ANALYSIS				X

X = MUST BE INCLUDED ? = MAY BE INCLUDED

Figure 124.

CONCLUSION

A list of parameters which must be considered in defining a proposed design for a visual simulator has been presented. This checklist should give the NTDC Project Engineer a better control over the characteristics of the planned trainer and to the bidder and contractor a better definition of what is desired. The specific parameters and their values have not been validated through transfer of training or proficiency evaluations or in some other way identified as major contributors to an adequate visual simulator. But in terms of what the TV and optical industries use now the visual simulator should be adequately defined. Further research is needed to establish the criteria and tolerances for a number of the parameters.

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APPLICATION OF STATISTICS TO MAINTAINABILITY ENGINEERING

LYMAN A. WHALEN
Maintenance Engineering Division
Naval Training Device Center

Space age engineering and technology have resulted in the development of maintainability to a stage where it is now considered a true engineering discipline. In the past, maintainability was defined in qualitative terms; now it can be defined in quantitative terms. It can be predicted with reasonable accuracy, and it can be measured and verified. For these reasons, maintainability is currently being specified as a requirement in military development programs.