FUNCTIONAL SPECIFICATION OF TRAINING DEVICES WITHIN A TOTAL TRAINING SYSTEM CONTEXT

J. S. Bresee
The Singer Company - Link Flight Simulation Division
Binghamton, New York

ABSTRACT

The training systems industry has long recognized the need to base the design of complex and expensive training devices on specific training requirements. The numerous efforts that have been made to achieve this goal have encountered problems across a range of areas. User communities and procuring agencies have in the past been forced to struggle with these problems alone, but with the advent of total training systems acquisition, the system supplier must face this problem directly. Functional design techniques from engineering disciplines have proved insufficiently sensitive to required student behavior. Media selection models from ISD, on the other hand, are not optimized to support the development of a new device. The use of ISD media models has identified training requirements for which simulation is needed but without sufficient detail to support engineering decisions. There is a clear need for a media design process which is oriented around training requirements and which yields information required for device engineering. This paper outlines a process which appears to have promise as a response to these needs.

INTRODUCTION

The communication of training requirements from those who must use a training device to those who must build it has long been perceived as a major hurdle to be cleared in the development phase of a program. Evolutionary changes in the ways in which the services procure training capabilities have caused the need to reexamine this communications process and the specifications on which procurements are based. This paper attempts to define this basic issue, and describes a process for addressing some of its implications.

Statement of the Issue

The clear trend toward the procurement of total training systems has shown itself to have an equally clear corollary: training system suppliers will not receive detailed technical specifications on which to base simulation and training device engineering. Instead, customers will simply provide a list of training requirements; a definition of the use to which the device will be put. And if the procurement is truly a total system procurement, this list is not very extensive. The contractor who wants to offer a total training system must himself take on the role of the user. He must carefully analyze the mission which the students who use his device -- within a curriculum which he must provide -- will perform at the conclusion of their training. The decision as to what to build is left squarely in the hands of the vendor, and he often must guarantee the post-training proficiency of the students who use it.

This corollary trend offers the simulation and training industry an unprecedented opportunity to satisfy its customers. Not only are we told exactly what the customer hopes to accomplish with our product, but we are encouraged and often required to perform the detailed investigations of the end goal ourselves, thus making sure that we fully understand in our own terms just what our customers truly need. The supplier of a total training system more accurately becomes his own customer, putting to use in his own curriculum the devices that he has built. This subsumption of our industry's traditional role within a larger frame of reference has given us all a new set of hurdles to get past. We must now come to terms with the problem that until now we have simply waited for our customer to solve: the conversion of training requirements into device blueprints, translating the jargon of behaviorists into the notation of engineers. The training system supplier is committed to supplying proficient operators and maintainers of deployed systems, and must guarantee the results. We now come up against it; it's our money. How can we make the best use of it? How can we obtain all the training capability we need to live up to our guarantee without spending more than our projected profits?

Overview of Approach

We've already recognized that the training system supplier's problem is not new; our customers have struggled with it right along. Users and acquisition agencies have employed various procedures and processes to come up with device specifications that accurately reflect the training need, but the most successful of these have borne a close resemblance to the ISD process as described in MIL-T-29053B(TD). In spite of the frustrations that have been encountered with processes labeled "ISD", this basic approach is still the most reliable route to an organized set of training requirements and to the data which is derived from it.

The methodology described here is based upon training requirements data generated by the ISD process. It offers a systematic method for compiling functional requirements data, and data structures suitable for automation. It is based upon training requirements stated as behavioral objectives, and thus resides within the ISD process, performing the role of the media selection function of MIL-T-29053. This technique is also engineering-oriented in that device characteristics are specifically addressed in detail. Its major strength is that it can be applied in detail by non-engineers, thus maintaining a clear orientation toward training requirements while yielding a rank-ordered set of required device functions.

BACKGROUND

In order to respond to this opportunity, the Link Flight Simulation Division has examined the traditional media selection process and the techniques used by other training system suppliers to determine a workable design process for ensuring the utility of the simulators and other training media which make up a total training system. The process described builds upon the early work done by Hughes and O'Neal ([1]) and their definition of a matrixed media selection model based on capabilities and requirements profiles. This model defined a media pool, each member of which had been evaluated and rated on specific training media capabilities, from which were generated capability profiles for each pool member. The capability profiles of pool members were compared against the profiles of specific requirements for each objective. As implemented, the Hughes/O'Neal process required that these data be entered into a set of automated files which were then compared. The result was a rank-ordered list of acceptable media types for each objective. A user of the model would then manually test various groupings of objectives to arrive at an effectively mediated set of lessons.

The technique presented here builds on the matrixed relationship of available capabilities to capabilities required as employed in the Hughes/O'Neal process. This approach allows a structured examination of the overall impact of the data while still permitting independent examination of each training requirement. The enhancement to the Hughes/O'Neal model which this technique adds is independence from a predefined media pool. Instead of media capabilities, functional characteristics of the job environment are used to develop requirements profiles for each behavior. Available media are evaluated on their capability for manifesting these characteristics. Job characteristics which cannot be accommodated by existing media define the media (e.g., simulation) engineering task. This ability to operate without a closed set of preconceived possible outcomes is what distinguishes media design from media selection.

MEDIA DESIGN PROCESS

The media design process takes as its primary input data a set of behavioral statements of required student performance as generated by the front-end analysis phases of the ISD process. The second major ingredient of media design is an organized set of the functional characteristics which make up the job environment. In the case of a training system for operators of a specific platform, this listing will include as a minimum a hierarchical listing of the platform components which the operator must see or manipulate to perform the job. Additional information requirements include listings of relevant environmental conditions, operational/tactical conditions, and command/control/communications/intelligence factors. Depending upon the job to be trained, other sets of functional characteristics can be defined. The main point here is to identify as many relevant job characteristics as possible that might impinge upon the training environment. In addition, room should always be left for additional characteristics that are discovered as the media design process proceeds.

The media design process operates through the successive and independent consideration of each behavioral statement to identify the minimum set of functional characteristics which must be present for that specific behavior to be performed. Personnel with job-related expertise together with training design personnel assign required functional characteristics to each training requirement. This information is stored in an automated virtual matrix which is then processed to determine trends in the set of required characteristics. For instance, a certain visual effect may be required for only a small number of training requirements. The data base allows rapid identification of these requirements in order to evaluate the importance to the overall training system of the inclusion of this visual effect. Should one of the requirements be especially difficult or critical, the effect will likely be included. On the other hand, cost analysis may show that the impact of training these tasks in the job environment is more economical than developing the simulated effect.

DATA REQUIREMENTS AND STRUCTURE

While most accurate outputs result from the use of detailed training objectives, successive approximations of media requirements can be developed from each step in the ISD process which yields a set of behavioral statements. In the early stages of a program, it is not unreasonable to examine job tasks for functional requirements. However, job tasks are not always the direct progenitors of training requirements. In order to avoid an over-engineered medium, it is essential to refine this initial estimate by examining training objectives in addition to job tasks.

The critical set of data required for this process, regardless of the stage in a program where it is implemented, is the listing of functional characteristics. In developing this, a designer starts with a list of platform characteristics. Identifying platform characteristics which impact training is usually accomplished readily through the same technical documentation and sources of subject matter expertise used to develop the job task analysis and objectives hierarchy. A list of platform characteristics should include components, functions and features, and operating capabilities. This list of platform characteristics is then expanded to include relevant environmental, tactical, and similar job characteristics. The final listing should represent each element of the job environment which is suspected to have a training implication.

Other functional characteristics are relevant as well. In order to apply the process to the full range of training system media, functional characteristics that are unique to training environments must also be addressed. The Hughes/O'Neal model provides a listing of characteristics in this category, and makes a good starting place for the development of a project-specific list, or an updated master list of non-job-related functional characteristics.

The structure which contains these data has been referred to as a virtual matrix. This term is used because the matrixed data form a multi-dimensional structure not easily diagrammed. The basic matrix is made up of rows defined by the training requirements matched against columns defined by the functional characteristics. The data contained in this basic matrix is more conveniently presented as an indented list. Appendix C presents such a list of functional characteristics associated with training requirements. Each entry in this list can be thought of as one of the cells of the virtual matrix where a "hit" has occurred.

In addition to these two dimensions, each cell in such a matrix can be thought of as containing additional dimensions. Each training requirement generates multiple training events. Assuming for simplicity's sake that each training requirement is itself a single behavior, it must first be introduced, then perhaps explained and elaborated, eventually practiced over multiple iterations, evaluated, and finally reviewed periodically for proficiency maintenance. The sequentially more demanding conditions and standards which attach to each behavior define the specific objectives from which training events are developed. Within each row of the parent matrix, these objectives define another dimension.

Each training requirement has still another set of characteristics associated with it in addition to the functional characteristics of the job environment and the multiple incidences of the training behavior. Each training requirement also has a specific set of instructional strategy requirements which must be addressed. Whether the set of available instructional strategies is defined by some taxonomy of behavior or by the available capabilities of an a priori media pool, this set defines still another possible dimension of the matrix.

Determining the fidelity with which each of the functional characteristics is represented has historically been one of the most critical training design issues. In some cases, arbitrary "levels" of fidelity have been established by definition. In others, physical properties of required stimuli and response capabilities have been listed and then associated with each training requirement. In either case, however, the final specification for the training medium has been determined through negotiation between training device engineers and user representatives. Fidelity decisions are most accurately made when the behavioral requirement has been reduced in size and scope far enough to permit a binary judgment: some physical property either must be present or is not required; a simple yes-no decision. Establishing the conditions necessary to make a decision at this level requires an extremely detailed analysis of required student behavior as well as an equally detailed analysis of the job. Sooner or later, designers must reach the point of saying whether or not a specific switch must be present for a given behavior to be performed. At low enough levels, what is often found is that the particular physical element need not be present as long as its function is present: a touch panel can functionally represent the action of a toggle switch. Following this line of thought, higher-fidelity devices only become necessary when higher-order tasks are trained. This notion has a sound basis in reality. The need for high-fidelity simulation to support "mission rehearsal" training is not in question. The level of behavior for which this level of fidelity is cost-effective is decidedly in question. By analysis in detail, and systematic compilation of decisions made in detail through an approach similar to the virtual matrix concept, this problem can be directly addressed.

APPLICATION PROCEDURES

Following is a proceduralized overview of the media design process. The steps listed below summarize the foregoing discussion, identifying the personnel involved in each step:

- SME's compile a list of characteristics of the platform
- Simulation engineers review list, identifying areas requiring clarification, deletion, or addition
- Team identifies additional relevant characteristics of the operating environment
- Training analysts furnish hierarchy of training behaviors
- SME's allocate characteristics to behaviors
- Analysts review allocations, determine clusters of characteristics by curriculum events through interaction with the automated data base
- Simulation engineers specify functional capabilities of existing devices
- Training analysts identify those requirements not met by existing equipment
- Simulation engineers review resulting functional requirements, flagging those which are likely to be difficult or expensive.
- Training analysts and SME's review flagged items, verify necessity
- Team generates a consensus report of unmet requirements requiring a new training medium
- Cost studies to determine most productive clustering of features are performed
- Final grouping of functional characteristics is defined; functional design process is complete

EXAMPLE OF APPLICATION

The media design process has been used on several recent design efforts. An example of such a project is an internal study conducted to define the training environment required for AH-1 helicopter gunners using a FLIR-equipped Telescopic Sight Unit (TSU). This project offers a small-scale look at the practical requirements of implementing the media design process. This project was prototypical in that it clearly highlighted both the benefits and drawbacks of the media design process in its current form.

Platform characteristics were first listed by extracting equipment components from the aircraft operating manual and associated technical publications. This approach allowed an initial list to be developed rapidly for subsequent review by subject matter experts. The same data sources were then used to identify job tasks at the behavioral level at which this functional specification was developed. This hierarchical task listing was again provided for SME review. Following the identification of job tasks, additional job characteristics were identified to represent the tactical environment under which the tasks would be performed. Sample portions of both task and functional characteristics listings are presented in Appendices A and B.

Following the development of these basic listings, each behavior was examined to determine the characteristics required for its performance. Using an automated data base, required characteristics were associated with behaviors to allow the generation of data summaries and the sorting of files to identify trends in requirements. A sample portion of the result of this task is presented in Appendix C.

In this study, the bridge from detailed functional requirements to a recommended device configuration was built inductively. Instead of deducing the possible media configurations and selecting among them based on additional criteria (such as cost), an a priori selection was tested against the data for acceptability. While not the most rigorous way to apply the design process, this approach is still useful and perfectly valid for cases where the acceptability of existing media must be determined. In this specific case, the initial medium of choice was not adequate in all respects, specifically in the available student interaction modes. The functional requirements data base was then used to test the adequacy of each of several possible enhancements, resulting in the addition of a simulated TSU left hand grip and TOW missile tracking handle. The final specification suggested that these capabilities be handled through the addition of an RS-232 interfaced joystick control, with the action switch separately mounted on a fabricated left hand grip.

Based on this inductive approach, the findings of the analysis were summarized in a table of recommendations, shown in Figure 1. Figure 2 is a block diagram of the resulting design concept. In reviewing these figures, it is important to note that additional factors

FINDINGS	RECOMMENDATIONS
-- Main requirements are for: o Line unit training of FLIR system. o Line unit gunnery refresher training incorporating FLIR	Portable device Include TSU-aimed TOW and turret functions
-- FLIR will be integrated with TSU; operation will be simplified -- Most students already qualified in use of TSU	De-emphasize 3-D controls; 2-D likely to be sufficient
-- Underlying behaviors indicate emphasis on visual tasks	Visual system
-- Basing concept indicates need for a portable, economical device	Visual system based on video display for low cost and portability
-- Field unit use indicates need for reduced instructor/operator requirements	Employ CBT technology
-- Field unit use indicates need for automated administrative support; e.g., automated student records	Employ CMI technology

Figure 3-1 FINDINGS AND RECOMMENDATIONS

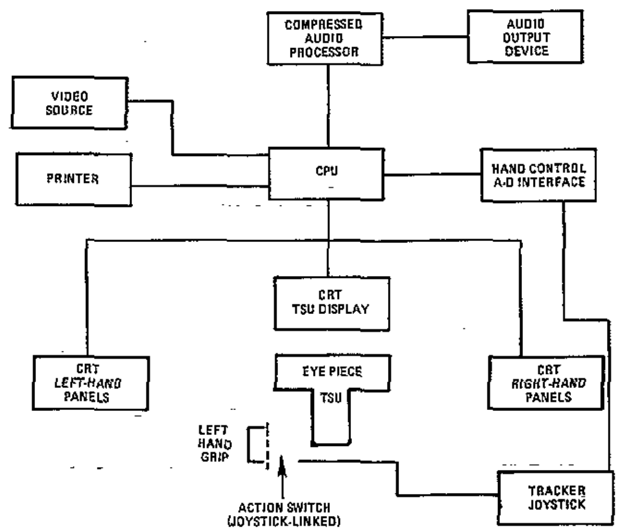

Figure 3-2 BLOCK DIAGRAM OF FLIR/GUNNERY PTT

present in the training environment were referenced in addition to the data yielded by the design process. The point to be taken is that voluminous design data cannot replace informed judgment regarding the training environment. This process is at best a means of obtaining a foundation for these judgments. However, even in this role, the media design process lends authority and justification to the final set of media recommendations.

ADDITIONAL USES OF FUNCTIONAL REQUIREMENTS DATA BASE

Although primarily envisioned as a design tool, the media design process generates a data base that serves an additional important purpose after training system implementation. The association of platform and operating environment characteristics with training behaviors as contained in the media design data base is the critical information structure for concurrency management. Through other data base structures, the training requirements are related to the training events where they are taught. Likewise, the platform and functional characteristics are related to the specific training media where they are represented.

One can clearly see that these relationships allow most of the critical concurrency questions to be readily answered for both training devices and the curriculum. Should a component of the platform be modified or replaced, these relationships allow the training system supplier to quickly identify each impacted training requirement by listing those behaviors associated with the platform characteristic being modified. Impacted lessons and training events can then be identified by listing the lessons in which impacted training requirements are taught. The media for these lessons are those which must be modified.

In addition to supporting concurrency management, the media design data base could provide the knowledge structure required for an expert system scheduler. In most cases, training requirements may be satisfied by several of the available media. This is so because during the design of the training curriculum, great care is usually taken to make maximum use of the most valuable, high-fidelity training media. For example, a flight simulator whose primary justification in the media suite is for mission-oriented training in a full flight scenario is often used for procedural training if the student load on the system does not fully utilize it for mission rehearsal. Should the student load temporarily increase, or should a particular student require additional simulator time to meet an objective that he finds difficult, the media design data base could be consulted for alternative media that meet the requirements for procedural training. The expert system scheduler could then assign these alternative media to students whose simulator time has been preempted.

ADDITIONAL DISCUSSION AND CONCLUSIONS

The summary functional specification that is prepared from the data yielded by the media design process of necessity does not directly address engineering requirements. It still requires a talented design engineer to determine the ways and means by which these required functions are incorporated into a technical specification for a training device. What the process does accomplish is the systematic allocation of specific platform functions, which the engineer has first reviewed and approved, to actual training requirements. In addition, by accomplishing this allocation separately for each training requirement, the media design process provides an estimate of the relative importance of these characteristics to be simulated through frequency counts of their allocation to training requirements. While the engineer still may not know precisely what the device will look like or how it will function, he does know precisely what it must do to be useful for training.

The media design process is maximally useful when employed as an integral part of a systematic training system design process under a comprehensive design data management plan. Its benefits are similar in nature to most other techniques arising from the basic ISD process: it provides a method for systematically handling comfortably small packages of information while ensuring that the entire range of data is considered. Training system design, including media design, remains a judgmental process. This technique increases the accuracy of these judgments by allowing them to be made about a reasonably sized piece of information. Were a designer required to estimate the mediation requirements for an entire training curriculum as a whole, the sheer number of training requirements would be a guarantee that the implications of many of them would be overlooked. By making judgments on smaller chunks of data, the designer reduces the size of the potential error.

The sample application discussed here was for a relatively small project involving only several hundred training requirements. The process is equally applicable to large efforts, but the size of the automated data base is greatly increased. In sizing computer support requirements for such an effort, Link's Training Systems Development group arrived at some very large numbers. The operation of a typical military aircraft generally involves between three and five thousand discrete tasks. Assuming that each of these tasks generates between five and ten subtasks, and each of these subtasks yields between three and five training objectives, the design team must deal with about 120,000 behavior statements (calculated using the midpoints of the above ranges) in carrying out media design. Lists of functional characteristics can easily be as large as 500 items. The arithmetic implied by these values yields a data base capacity of over 600 megabytes just to contain the data generated. This implies one thing very clearly: comprehensive training systems design is impossible without automation.

The media design model presented here has shown promise in a small application. Use of similar techniques in other organizations has shown the approach to be workable for larger programs. It is hoped that the industry as a whole will continue the development of this and similar techniques in order to develop a common set of tools that will allow us to understand and fully satisfy the broad range of training needs with which the defense community will continue to be confronted.

REFERENCES

1. A.S. Gibbons, A.F. O'Neal, D.R. Farrow, R.H. Axtell and J.A. Hughes "F-16 Training Media Mix." Defense Technical Information Center Report No. ADA 099841. March 1981.

About the Author

J.S. Bresee holds the position of Manager of Training Systems Design for the Link Flight Simulation Division of The Singer Company. His professional experience in the development and operation of aircrew training systems dates from 1977 and includes a wide variety of airframes and missions. Attached to Link's Training Systems Development Group, he and his staff are responsible for establishing methods and models for total training systems design, and for research and development of training methods, techniques, and new training technology.

APPENDIX A
TRAINING REQUIREMENTS EXCERPT

4.1.3.1.15	Set Gunner LHG HI LO MAG switch as desired
4.1.3.1.16	Depress LHG ACTION switch
4.1.3.1.17	Place gunner TSU reticle on target
4.1.3.1.18	Press LHG LASER switch
4.1.3.1.18.1	Positively hold LHG LASER switch in position
4.1.3.1.19	Press LHG TRIGGER
4.1.3.1.20	Release LHG TRIGGER
4.1.3.1.21	Release LHG ACTION switch
4.1.3.1.22	Release LHG LASER switch
4.1.3.1.23	Set TCP MODE SELECT switch to off
4.1.3.1.24	Set Gunner TCP LASER ARM to OFF
4.1.3.1.25	Set FLIR to OFF
4.1.3.1.26	Set Gunner LASER SAFE/TURRET DEPR LIMT switch to LASER SAFE/ TURRET DEPR LIMIT
4.2	Employ TOW
4.2.1	Employ TOW using TSU (Ref. TC 1-136 Task # 6058)
4.2.1.1	Perform TOW firing Checklist
4.2.1.2	Track TOW to target using TSU
4.2.1.2.1	Set Gunner TCP MODE SELECT switch to desired TOW setting
4.2.1.2.2	Set Gunner TCP LASER ARM switch to 1ST or LAST
4.2.1.2.3	Set TSU filter level to L
4.2.1.2.4	Set Gunner TSU LHG MAG switch to LO
4.2.1.2.4.1	Positively hold switch in before releasing
4.2.1.2.5	Focus Gunner TSU reticle
4.2.1.2.6	Set Gunner TSU RTCL knob as desired
4.2.1.2.7	Set Gunner TCP MISSILE SELECT switch to desired position
4.2.1.2.8	Set Gunner LASER RANGE MIN RANGE DISPLAY switch to DISPLAY
4.2.1.2.9	Set Gunner LASER RANGE MIN RANGE SET switch to desired minimum
4.2.1.2.10	Set Gunner LASER RANGE MIN RANGE DISPLAY switch to OFF
4.2.1.2.11	Set Gunner LASER SAFE/TURRET DEPR LIMIT switch to OFF
+4.2.1.2.12	Place Gunner HS reticle on target
4.2.1.2.13	Set Gunner SHC ACQ/TRK/STOW switch to ACQ
4.2.1.2.14	Release SHC ACQ/TRK/STOW switch to TRK
4.2.1.2.15	Place Gunner TSU reticle on target
4.2.1.2.16	Set Gunner TSU LHG MAG switch to HI
4.2.1.2.16.1	Positively hold switch in position
4.2.1.2.17	Maneuver SHC track control stick as required to keep TSU crosshairs on target
4.2.1.2.18	Press LHG LASER switch
4.2.1.2.18.1	Positively hold switch in position
4.2.1.2.19	Press and hold TSU LHG ACTION switch

APPENDIX B
ASSOCIATED FUNCTIONAL CHARACTERISTICS

Location: Gunner Instrument Panel

A0000	Tracker
A0100	Track Control Stick
A0200	ACQ/TRK/STOW Switch
A0210	ACQ Position
A0220	TRK POSITION
A0230	STOW Position
A0300	COSNT OVRD Switch
D0000	TOW Control Panel
D0100	MODE SELECT Switch
D0110	Off
D0120	TSU/GUN
D0130	STBY+TOW
D0140	ARMED
D0141	AUTO
D0142	MANUAL
D0200	TSU/SCA/EPS/MCA Unit Fail Indicators
D0300	BIT Switch
D0400	BF Knob
D0500	LRD Knob
D0600	CAMERA Switch
D0700	LASER ARM Switch
D0710	Off
D0720	1st
D0730	Last
D0800	OFF/PWR ON/ARMED/TEST System Status Annunciator
D0810	OFF
D0820	PWR ON
D0830	ARMED
D0840	TEST
D0900	TSU RTCL Switch
D0910	OFF
D0920	BRT
D1000	WIRE CUT Switch
D1100	MSL/Barberpole Missile Status Indicators
D1110	MSL
D1120	Barberpole
D1200	MISSILE SELECT Switch
D1210	missile 1
D1220	missile 2
D1230	missile 3
D1240	missile 4
D1250	missile 5
D1260	missile 6
D1270	missile 7
D1280	missile 8
E0000	Laser Range Finder Control Panel
E0100	MIN RANGE SET knob
E0200	DISPLAY switch
E0210	DISPLAY
E0220	OFF

APPENDIX C
TRAINING REQUIREMENTS AND ASSOCIATED FUNCTIONAL CHARACTERISTICS

C1120 LASER SAFT/TURRET DEPR LIMIT

4.2 Employ TOW

4.2.1 Employ TOW using TSU
(Ref. TC 1-136 Task # 6058)

4.2.1.1 Perform TOW firing Checklist
C0100 ARMED/STBY Indicator
C0200 PILOT IN CONTROL Indicator
C0300 PLT/GNR/EIA/GO Indicators

4.2.1.2 Track TOW to target using TSU

4.2.1.2.1 Set Gunner TCP MODE SELECT switch to desired TOW setting
B0210 G Battle Flag
B0220 A Battle Flag
D0100 MODE SELECT Switch
D0140 ARMED
D0141 AUTO
D0142 MANUAL
D0800 OFF/PWR/ON ARMED TEST Sys Status Annunc.
H0200 0 - 3 miles
H0210 Reliable ID possible on all potential trgts & obstructions

4.2.1.2.2 Set Gunner TCP LASER ARM switch to 1ST or LAST
D0700 LASER ARM Switch
D0720 1st
D0730 Last

4.2.1.2.3 Set TSU filter level to L
B0400 Filter Select Lever
B0900 TSU RTCL Switch

4.2.1.2.4 Set Gunner TSU LHG MAG switch to LO
B0100 Left-hand grip switches
B0111 LO

4.2.1.2.4.1 Positively hold switch in before releasing
B0100 Left-hand grip switches
B0111 LO

4.2.1.2.5 Focus Gunner TSU reticle
B0600 Focus knob
F0200 Day
F0300 Dusk
F0400 Rain
F0500 Fog
F0600 Dust