PERFORMANCE MEASUREMENT SYSTEM--IT'S TIME HAS COME

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ABSTRACT

The attempts to build performance measurement systems into simulation have been with high expectation, but have ended with limited outcomes. More often than not the performance measurement system was envisioned, implemented, and then set aside. Instructors did not include it among their tasks for simulator operation and instruction. Some have said the instructor operator station (IOS) was so complex that the instructor/operator did not have the time to also work the performance measurement system. Now with the growth in both computational power and software strength, the instructor/operator role can be significantly reduced. Integration of technologies such as voice recognition will simplify operator tasks and give time for more focused student training. Others have shown that the instructor does not allow deviations in student aviation training, so the traditional performance measurement of flight deviations was of little value to the instructor. Knowledge of instructor support systems has improved and understanding of performance measurement has matured. Trend analysis tied with artificial intelligence can become an advisor to the instructor, including the memory of learner profiles and the store of appropriate instructional strategy options. Close monitoring of student performance will give a capability for the right feedback to reinforce good choices and correct responses. The performance measurement system will not only improve training effectiveness, it will also improve training efficiency, helping reduce the overall life cycle cost. Thus the performance measurement system makes a weapon system more affordable. The time has come for the realization of the long held vision that performance measurement systems become an integral part of the total training system. This paper presents the historical background that has given us the lessons learned from past efforts in performance measurement. An approach is presented for development of a performance measurement system within the context of a total training system. This performance measurement system becomes a career companion for a full life-cycle of performance improvement.

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INTRODUCTION

The vision for simulation and training is to make performance measurement systems an integral part of the total training system. During initial qualification, the performance measurement system would provide the instructor and the student timely feedback for guiding consistent performance improvement. Following graduation, the performance measurement system would continue as a companion to aircrews throughout their flying career. Through the course of continuous performance improvement, metaskills would be developed and honed for employment in those critical warfighter situations. Tacit knowledge would emerge, establishing expertise in every facet of mission fulfillment.

Up until now realization of this vision for performance measurement systems has been fraught with fleeting expectations. Planning and programming were in the right spirit, but fell short of the vision. Too many attempts resulted in parameters measured but not used, so the feature was turned off. Feedback indicated that the performance measurement systems were too complex to use, too confusing to implement, or too difficult to accomplish.

Instructional Technology

The field of Instructional Technology has updated the Instructional System Development (ISD) process to center all functions around evaluation for feedback in all phases of the process, including continuous performance improvement (Figure 1). This model incorporates the training system functions found in successful total training system implementations (Golas & Bills, 1993). These functions are management, administration, instructional delivery, and training system support. Also included are the traditional functions of instructional system development (ISD) which are analysis, design, development, and implementation. Evaluation is center to all functions. The whole mindset of this ISD process model is continuous quality improvement.

Instructional design is a technology for the development of learning experiences and environments which promote the acquisition of specific knowledge and skill by students (Merrill, Drake, Lacy, Pratt, & ID2 Research Group, 1997). Performance measurement aids the technology of instructional design during empirical tests for verification of instructional strategies. The acquisition of different types of knowledge and skill require different conditions of learning (Gagné, 1985). If an instructional experience or environment does not include the instructional strategies required for the acquisition of the desired knowledge or skill, then learning the desired outcome will not occur. Performance measurement verifies the acquisition of knowledge and skill. Performance measurement supports instruction by monitoring student performance and providing feedback as to the appropriateness of the student's learning activities and practice performance.

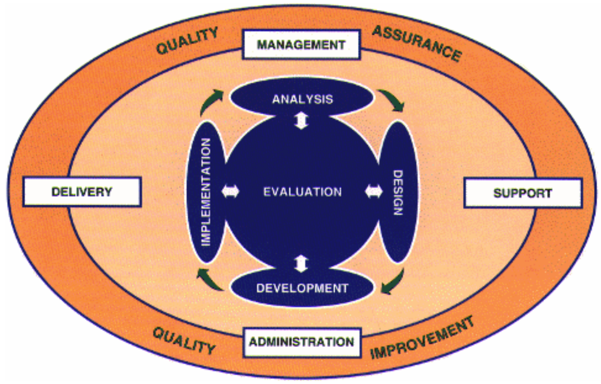

***Figure 1*. Instructional System Development (ISD) Process (SWRI, 1998)**

Human Performance Technology

The field of Human Performance Technology (HPT) has implemented a process for continuous performance improvement. This process combines performance analysis, cause analysis, and intervention analysis for realizing personal growth through sustained development across a full career. Kaufman (1998) suggested that in the past the approach to dealing with the higher levels of improvement (Kirkpatrick's levels 3 & 4; Kaufman & Keller's level 5) has been "dumbed down" because of inability to measure, the feeling that it was too complex, too confusing, or too difficult to accomplish. He said, "If performance improvement specialists only deal with that which

Table 1

Grading Criteria Used for Student Progress Reports in Aircrew Training

Level 1.0	The student demonstrated a lack of knowledge about the task or made major deviations or omissions that made accomplishment of the task impossible. The instructor was required to demonstrate proper accomplishment of the task.
Level 1.5	The student demonstrated limited knowledge of the task. Although the student can begin the task, performance deteriorates quickly and extensive instructor interaction is required to maintain safe accomplishment.
Level 2.0	The student has a basic understanding of the task, but errors or deviations are significant and would jeopardize safety or mission accomplishment. Even under ideal conditions extensive instructor intervention is required for safety or mission accomplishment.
Level 2.5	The student made errors or deviations. Limited assistance along with frequent coaching by the instructor was essential for safe accomplishment of the task. The student has sufficient systems knowledge to make correct response when provided coaching by the instructor.
Level 3.0	The student accomplished the task successfully, but there were slight errors or deviations that the student could not correct. The instructor was required to provide coaching for smooth performance, but not for safe mission accomplishment. The student can perform under ideal conditions, but would have difficulty under adverse conditions.
Level 3.5	The student was able to accomplish the task safely and successfully with minor errors or deviations. The student was able to correct these minor errors, and no assistance was required from the instructor.
Level 4.0	The student performed the task without errors or deviations. No instructor intervention was required. The student has progressed beyond mere proficiency and could probably perform well under adverse conditions.

is not 'confusing' and 'difficult' then who takes responsibility for airplanes falling from the sky…" (p. 23).

HISTORICAL BACKGROUND

Early attempts to put performance measurement systems into simulation were centered around the instructor station. Lessons on how to integrate aircrew training simulation into a total training system took time (Bills, 1987; Nullmeyer & Rockway, 1984). Training effectiveness studies provided insight into the benefit of these performance measurement systems.

Weapon System Trainers (WSTs)

Two weapon system trainers (WSTs) were fielded in the early 1980's. One was the B-52/KC-135 WST at Castle AFB, California. The first attempt to bring the system online verified that the computation power for the level of simulation required was insufficient and the KC-135 was separated off without implementing integrated activity between the two aircraft crews. The second WST was fielded at Little Rock AFB, Arkansas. Armstrong Laboratory was invited to participate in the Follow-On Operational Test and Evaluation (FOT&E) for these WSTs.

B-52 WST. In 1984 the B-52 WST was certified for initial qualification training. The development team had worked closely with Link engineers to build into the crew stations a performance measurement system. The parameters were tested to validate agreement with Strategic Air Command (SAC) directives for Standardization/ Evaluation (Stan/Eval) performance checks. Instructors were taught how to capture the data during the mission and then play it back during debrief. However, within a few months after the WST was certified for training, the performance measurement feature was turned off. The instructors found it of minimal value for initial qualification training. The reason the performance measurement system was seen as having minimal value was related to an earlier finding from deriving a methodology for assessing.

Table 2

Applying Advanced Learning Principles to a Performance Measurement Scheme

	Individual	Team
Process	• Decision Making Processes • Task Strategy • Information Seeking	• Coordination Behaviors • Communication Flow • Team Strategies
Outcome	• Accuracy • Timeliness • Decision Rules	• Mission Effectiveness • Aggregate Latency & Accuracy • Error Propagation

Houtman, 1981). During the search for a sensitive measure to assess changes in student performance, the use of flight parameters as the criterion revealed that there were actually minimal deviations allowed by instructors from established, safe flight patterns. The instructors were maintaining control of the aircraft until they felt confident to gradually yield control to their students.

Based on the understanding of how instructors train, a methodology was derived for assessing transfer of training by using degree of instructor input. The performance measurement scale (Table 1) used during FOT&E was changed from number of deviations to degree of instructor involvement. The seven point scale started with total instructor demonstration (level 1.0) and progressed to the top with no instructor intervention--solo (level 4.0). As a general rule, the initial proficiency for qualification was defined by achievement of level 3.0 (AFH 36-2235, 1993). This rating scale was used in the training effectiveness studies accomplished for the B-52 and the KC-135 FOT&E's at Castle AFB, CA., and also the C-130 WST FOT&E at Little Rock AFB, Arkansas.

The training effectiveness study for the B-52 WST was accomplished in the same year that the B-1 was being fielded. The Combat Crew Training Squadron (CCTS) at Castle AFB was directed to produce twice the number of copilots without increasing the number of flying hours. The only variable was the new WST. Various training options were tested to study the effect of the WST training on reduction in flying hours required to achieve checkride proficiency. A combination of part-task and full-mission training was identified and the required copilot production was met (Bills, 1987).

B-52 ARPTT. During an earlier study using the B-52 Air Refueling Part Task Trainer (ARPTT), the CCTS found that training to proficiency first in the simulator shorted by a third the time required to achieve proficiency in the aircraft (Nullmeyer & Laughery, 1980). A terminal proficiency was well defined and was accompanied by a training syllabus. Instructors assessed progress in the simulator. They were allowed the flexibility to provide the training they felt best met the needs of each student.

C-130 WST. The C-130 WST FOT&E covered not only initial qualification training, but also mission qualification and continuation training (Nullmeyer & Rockway, 1984). The study was accomplished in three phases. Data collected included proficiency ratings, instructor input ratings, and selected performance parameters. Amount of instructor input appeared to be a major index of student proficiency.

> Instructor ratings were based on the degree of instructor inputs. Instructor ratings of student proficiency indicated significant improvements across sorties. Instructor inputs decreased dramatically over sorties in a manner that was highly correlated with increasing proficiency ratings.... When both performance parameters and instructor inputs were used to predict proficiency ratings, instructor inputs almost completely overshadowed all other predictor variables...The relative small change observed in inflight performance parameters over sorties suggest that instructors allowed very little deviation from acceptable standards during the accomplishment of these maneuvers. (p.436)

Table 3

Comparison of Novice and Expert Cognition

Novice	Expert
Recalls on raw memory	Uses chunking and schemas to remember relationships and groups
Classifies problems according to concrete similarities	Classifies problems according to underlying relationships
Focuses on specific features of a problem and tries to link them to a memorized formula	Focuses on the big picture and looks for relevant principles
Relies on disorganized general knowledge	Relies on hierarchically (concrete to abstract) domain-specific knowledge
Considers a large number of alternative and works through all logical possibilities	Cuts the problem down to size by quickly identifying relevant schemas and then uses them to analyze, categorize, solve.
Works backward (unknowns to givens using mean-end analysis).	Works forward; uses shortcuts, estimates ballpark answers, converts unfamiliar problems to familiar one.
Focuses on problem solution rather than on problem-solving process.	Focuses on problem formulation and problem-solving process and knows solution will come.
Has little self-awareness of the strategies being used.	Has great self-awareness and a plan for the strategies being used.

Instructor Operator Station (IOS). Another factor in achieving the benefits of simulator training was the complexity of the instructor operating stations (IOS) for the WSTs. Due to IOS complexity instructors either missed student activity or overlooked simulator inputs. Decreasing IOS complexity was a critical need recommendation for improving simulator-instructor proficiency (Nullmeyer & Rockway, 1984).

Simulator Instruction Techniques

A comparison of simulator instruction techniques with inflight instruction techniques revealed necessary difference in order to make effective use of simulator training capabilities (Caro, 1978). Instructors were more effective when they were taught simulation training techniques such as adaptive training, performance playback, backward chaining, and automatic performance monitoring. For example, when new copilots were taught to land in the B-52 WST using backward chaining, the “wing rock” problem of overcompensating control inputs was gone before the copilots ever entered the aircraft. Teaching instructors in assessment also improved standardization of their “expert” judgment.

Naval Air Warfare Center. Extensive research at the Training Systems Division of the Naval Air Warfare Center, Orlando, Florida, has given further understanding of performance measurement in context of decision making and team performance (Cannon-Bowers, 1997). Performance measurement has three key elements. First, describe behavior to capture moment-to-moment changes and capture critical interactions. Second, evaluate behavior to establish standards of performance and multiple bases or methods. Third, document causes of behavior to show contributing factors, task and mission parameters, and any diagnostic information. Out of this research has come a performance measurement scheme for individual and team activity, presented by implementation process and expected outcome (Table 2).

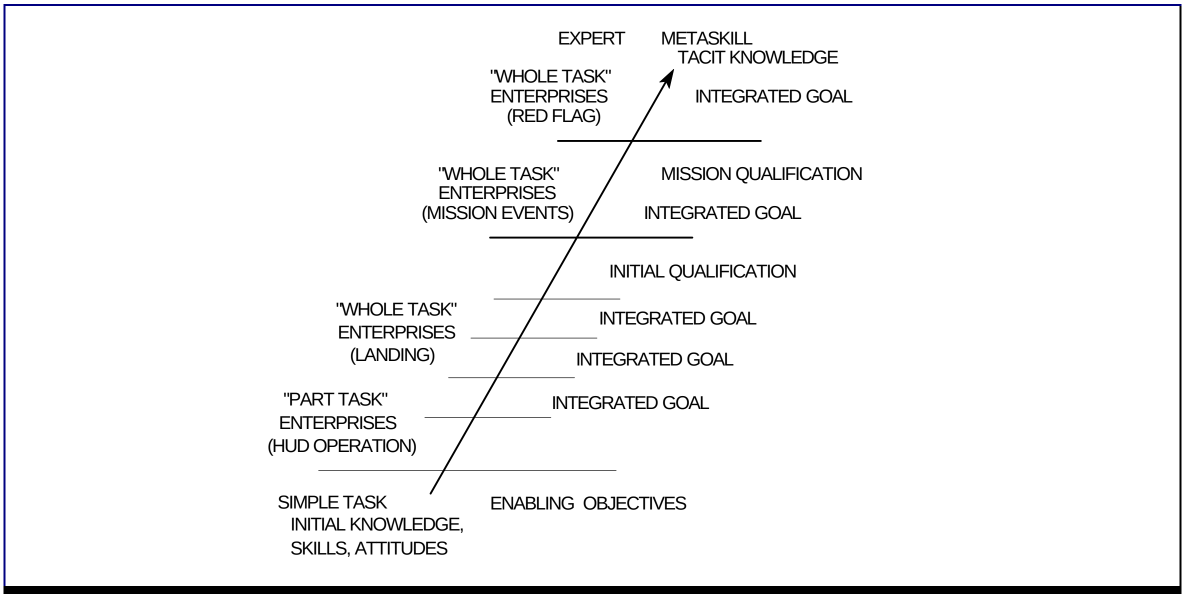

Figure 2. **Development of Metaskill Through Simple to Complex Pilot Training Continuum**

Novice vs. Expert

Closely associated with performance measurement has been the documentation of the nature of expertise (Cannon-Bowers, 1997). Experts have a pattern recognition, an ability to encode entire cue patterns as opposed to a conglomerate of individual cues. Experts also have the ability to make situation assessment, relying on memory templates and stored mental models. They have critical thinking skills using metacognition and mental simulation. Tennyson (1991) summarized the differences between novice and expert cognition, showing that performance of novices changes to a different set of factors when they become experts (Table 3). Spears (1983) defined experts as having a metaskill, the complex skill of adapting, monitoring and correcting in complex performances that integrates all learning process.

Cockpit Resource Management (CRM). The study of team coordination and performance during combat mission training (Silverman, Spiker, Tourville, & Nullmeyer, 1997) at Kirtland AFB, New Mexico, concluded that the wrong factors were being used to assess improvement in cockpit resource management (CRM). The tactical team resource management (T^2RM) measurement model was substantiated by the poorest performing crews having the lowest overall T^2RM process rating whereas the highest rated crews received the largest crew performance sums. T^2RM focused on three subprocess areas. First was strong tactical component in which combat skills were emphasized as opposed to attitudes or interpersonal relationships. Second, emphasis was on the behavioral processes of the entire team, including “data hooks” to the extended team (intelligence, planners, weather, airborne command, etc.). Third, management of multiple and diverse resources in a dynamic environment. Management was covered throughout the entire course of mission, including planning.

ELEMENTS OF PERFORMANCE MEASUREMENT SYSTEMS

Schmidt, Gibbons, Jacobs, and Faust (1981) concluded that a complete performance measurement system included: (a) identification of student readiness to advance or graduate; (b) production of administrative reports and records; and (c) feedback information for maintaining system quality control. Performance measurement needs to sustain development beyond initial and mission qualification into continuation training.

Instructional Strategies

A performance measurement system should be closely tied to the overall instructional system design. Instructional strategies should be identified which are known to achieve the desired outcomes. Instructional design for complex mission tactics and joint-warfare processes should include strategies for integrating human activities. These strategies will build schema, employ enterprises, and achieve metaskills (Fishburne, Spears & Williams,1987).

Schema. Schema govern cue and response selectivity so they are attuned to goals and conditions of performance. Training begins with establishing schema and then using them in progressively more complex activities, or enterprises. Although schema development is a cognitive activity, performance measurement can reflect personal progression in formation and use of schema.

Enterprise. An enterprise is a purposeful, planned activity that combines multiple objectives in pursuit of a comprehensive purpose or goal. Progression moves from simple individual objectives to the more complex enterprises, developing along the simple-to-complex continuum. Performance measurement gives feedback about goal achievement as well as the effectiveness and efficiency of the instruction.

Metaskill Continuum. The vision is fulfilled with the outgrowth of expert metaskills bolstered by tacit knowledge (Figure 2). Implementing performance measurement becomes more challenging beyond initial qualification, but performance improvement is still expected all the way through to metaskills.

Technology Advances

In addition to advancements in performance measurement systems, there have been advances in related technology. Speech recognition, 3D, and stereo improvements can enhance instructional tools and reduce instructor workload. Significant developments in computing power on smaller and smaller chips, improved software languages and development processes such as structural modeling, emerging high level architecture (HLA), joint synthetic environments, and interoperability standards all promise to improve training efficiency as well as effectiveness.

Information management, Internet, and data repository technology have made significant progress. Demand has been high so that the investment in research and development is advancing the market quickly. Tools like Oracle 2000 have reduced the time to implementation and have expanded the functionality available. Leaders have customers worldwide providing a wealth of understanding, many of which apply to training systems.

Now with the growth in technology, the instructor workload can be significantly reduced, giving time for more focused student training. Knowledge of instructor support systems has improved and understanding of performance measurement has matured. Trend analysis tied with artificial intelligence can become an advisor to the instructor, including the memory of learner profiles and the store of appropriate instructional strategy options. Close monitoring of student performance will give a capability for the right feedback to reinforce good choices and correct responses.

SYSTEM DEVELOPMENT

The time has come to put it all together, take the lessons learned and achieve the vision for a comprehensive performance measurement system. Achievement of this vision will require an integrated process team (IPT) approach.

Use Established Process

The IPT approach brings together the right players covering the full life cycle of the development system. The Performance Measurement IPT members include an instructional/human performance technologist, a training systems engineer, information management engineer, a logistics support analyst, expert performers, and the customer representative. The IPT will follow established processes for analysis, design, development, and implementation. Evaluation will be center to the process so there is a continuous feedback loop. Three fundamental processes will be followed: performance analysis, cause analysis, and intervention analysis.

Total Training System Design. Performance Measurement System will be designed as an integral part of a total training system. The data hooks for performance feedback will extend to the operational environment.

The scope of the design will cover the complete career path of the performer, such as command pilot or maintenance crew chief. During initial qualification, the performance measurement system would provide the instructor and the performer timely feedback for guiding consistent performance improvement. Following graduation, the performance measurement system will continue as a companion to crewmembers throughout their flightline career. Through the course of continuous performance improvement, metaskills will be developed and honed for employment in those critical warfighter situations. Tacit knowledge will emerge, establishing expertise in every facet of mission fulfillment.

Data Repository. A data repository will be established to support IPT activities during development and continue support after implementation. Traceability of requirements will be established at the beginning. The data trail will follow through allocation of requirements to each training system function, allocation of functions to each component, and validation back to requirements during test and evaluation.

Core Competencies. Competencies will be defined following process steps similar to the following: (1) Define the mission to be performed; (2) Describe the major outcomes or accomplishments required to achieve the mission; (3) Define performance standards for each major outcome; (4) Identify known barriers to achieving the performance standards; (5) Determine which barriers will be best overcome by training the person; (6) Determine a metric which will indicate performance improvement; (7) Determine a method of data collection, analysis, and feedback. (Esque & Gilbert, 1995).

Use What Works

Trade studies during synthesis will focus on current technology, "what works" today. Lessons learned will be applied as appropriate. The system design will include a quality improvement plan for tomorrow. Attention will be given to the needs of instructors, performers, managers, and maintainers.

Instructor Needs. Instructors need tools that aid instruction, reduce extraneous workload, and give performance feedback. The goal will be an intelligent instructor advisor capable of supporting the instructor during the entire syllabus across all training media, including the aircraft. This advisor will be knowledgeable of available aids and resources, will monitor student progress, and will provide recommended alternatives, individualized for the student and the instructor. This advisor accomplishes all retrieval and set-up. This advisor interfaces directly with the training management system and can present programmed data reports on demand.

The performance measurement system will have real-time performance monitoring, analysis, and feedback. In simulation, this data will include information such as setup, timing, mission plan, flight variables, and input responses. Tied to the real-time monitoring will be pre-selected settings and reference points for time, person, and event. The instructor will have the option to "flag" an event as it occurs for reset, playback, or debriefing. The established checklists and emergency procedures will be supported with feedback monitoring. For complete missions, the performance measurement system will provide stored data for post-mission debriefing.

Performer Needs. Performers need tools that aid learning, reduce extraneous workload, and provide performance feedback. The goal will be a companion advisor capable of supporting the entire career path, including reentry after a period of other activity. This advisor will be knowledgeable of available aids and resources, will monitor personal progression, and will provide the desired course of action for performance improvement.

The performance measurements system will provide information on how the performer should proceed to succeed in accomplishing the immediate and long term goals, give feedback on successful skill and knowledge acquisition, and assess development toward expert mission performance. Feedback will be supportive.

Manager and Maintainer Needs. Managers and maintainers need the day-to-day pulse of the system and its components. The goal will be a management and support advisor capable of monitoring the entire training system, analyzing progress, and reporting results. This advisor will status instructors, performers, and training resources, and will provide recommended management and support actions for operaing within the constraints and human limitation of the system. Feedback will support the attitude of continual quality improvement. This advisor will ensure training system availability and readiness.

Center Evaluation within Process

Evaluation will be centered with process as the method for a continuous feedback loop. Each phase of the process will use regular and recurring evaluation. The performance measurement system will be an outgrowth of evaluation.

During analysis, evaluation will occur at a system level and at a performer level. During system analysis, evaluation will be assessment of performance system requirements, functions, missions, and goals. During performer analysis, evaluation will be assessment of performance deviations, causal determinations, and action strategies.

During design, evaluation will be assessment of alternatives and prototypes in context of meeting mission and system requirements. Evaluation of mini-performer demonstrations will aid design decisions.

Development evaluation will be at a component and at an integrated system level. Initial assessment will be internal expert reviews. As development progresses to initial product, incremental test and evaluation will occur until operational capability is confirmed. Assurance will be given that the performance measurement system can perform the following functions: (a) Identification of performer progress as well as readiness to advance or graduate; (b) Analysis and delivery of progress reports and administrative records; and (c) Provide feedback information for performer performance improvement and training system quality improvement.

Implementation and operational evaluation will confirm that the day-to-day performance measurement activities meet customer requirements. During implementation, data collection will be intense. Feedback will be used to make the minor adjustments for a smooth operation. The performance measurement system will take over the training system operational evaluation function.

Cover Total Life Cycle

The performance measurement system will cover the full life cycle of the training system as well as the full extent of performer career development. The system will support instructors, performers, managers, administrators, and maintainers. The performance measurement system will operate within the human and system constraints and limitations. It will support all elements of the training system, ensuring availability and readiness for any contingency. The integration will include an approach for continual quality improvement.

SUMMARY

This paper presented the historical background that has given us lessons learned about performance measurement. An approach was presented for applying these lessons learned in the development of todays performance measurement system. This approach designs the performance measurement system within the context of the total training system. This performance measurement system becomes a career companion for a full life-cycle of performance improvement.

Now with the growth in technology, the instructor workload can be significantly reduced, giving time for more focused student training. Knowledge of instructor support systems has improved and understanding of performance measurement has matured. Trend analysis tied with artificial intelligence can become an advisor to the instructor, including the memory of learner profiles and the store of appropriate instructional strategy options. Close monitoring of student performance will give a capability for the right feedback to reinforce good choices and correct responses.

The vision for simulation and training is to make performance measurement systems an integral part of the total training system. During initial qualification, the performance measurement system will provide the instructor and the performer timely feedback for guiding consistent performance improvement. Following graduation, the performance measurement system will continue as a companion to crewmembers throughout their flightline career. Through the course of continuous performance improvement, metaskills will be developed and honed for employment in those critical warfighter situations. Tacit knowledge would emerge, establishing expertise in every facet of mission fulfillment.

The performance measurement system will also improve training efficiency, helping to reduce overall life cycle cost. The bottom line is that the performance measurement system makes a weapon system more affordable.

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