8.12 **Computer Based Training for Issuing Lightning Advisories at Cape Canaveral Air Force Station / Kennedy Space Center**

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1. INTRODUCTION

The 45th Weather Squadron (45 WS) recently implemented a new Computer Based Training (CBT) program covering all aspects of issuing lightning advisories in support of America's space program at Cape Canaveral Air Force Station (CCAFS) and Kennedy Space Center (KSC). This CBT was implemented in response to the lightning training challenges at 45 WS.

Space launch operations are extremely sensitive to lightning. Rockets in-flight can trigger lightning, which can lead to the destruction of the rocket. Numerous complex weather rules must be obeyed to avoid the lightning threat to launching vehicles (Roeder, et al, 1998). In addition to the danger during launch, the rockets and payloads require many weeks of outdoor work at the launch pad before the actual liftoff. The CCAFS/KSC complex is located in central Florida; 'Lightning Alley' of the United States. To help ameliorate these lightning sensitivities, 45 WS provides what is perhaps the most complicated lightning advisory requirements in operational meteorology. Two tiers of around-the-clock lightning advisories are issued for 5 NM circles centered on 13 points of operational sensitivity (Fig. 1). These lightning advisories are the most important day-to-day support provided by the 45 WS. In addition to protecting pre-launch operations, these advisories are also vital for personnel safety of over 25,000 people and resource protection for over $17 billion in facilities at CCAFS/KSC. This doesn't include the space launch vehicles and payloads, which can be worth $billions more. Forecasting summer thunderstorms in central Florida can be very difficult due to extremely weak synoptic drivers and plethora of boundary interactions. To help meet these sensitive requirements, the 45 WS uses the most diverse and most concentrated suite of lightning sensors in all of operational meteorology (Harms, et al, 1997) and has developed several local techniques for lightning forecasting (Roeder and Pinder, 1998).

New military forecasters are usually not adequately trained in pin-point lightning forecasting and certainly are not trained on the special lightning sensors at 45 WS. The lightning CBT was developed to help overcome these challenges and improve training on issuing lightning advisories by 45 WS.

2. LIGHTNING TRAINING CBT

The CBT was named Basic Orientation and Lightning Training (BOLT). SIGMAtech Inc., a professional interactive multimedia training company, produced BOLT, in close cooperation with 45 WS during all phases of development.

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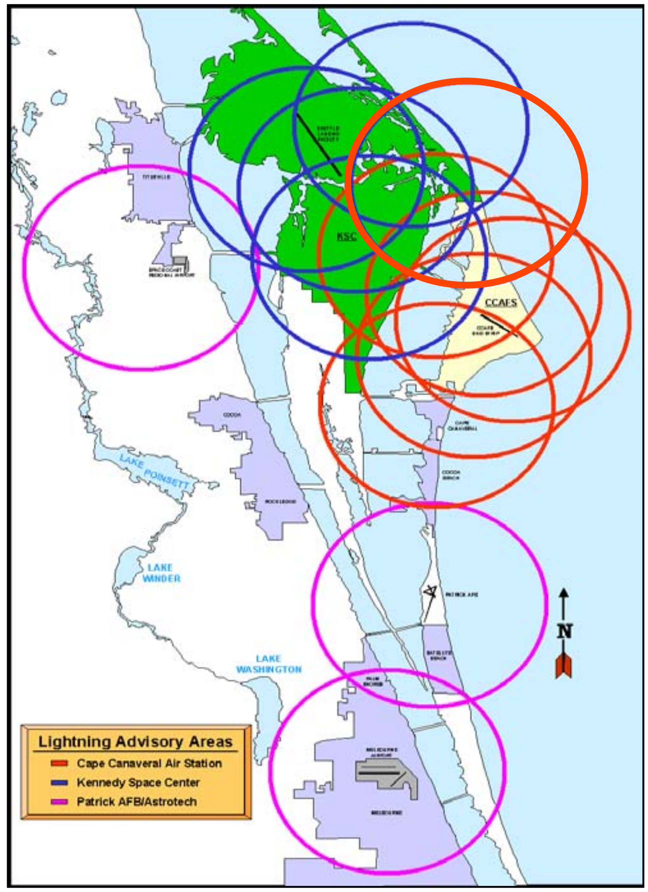


Figure 1. Lightning advisory areas supported by 45 WS are thirteen 5-NM circles centered on points of greatest operational need. Considerable overlap complicates issuing lightning advisories.

2.1 Computer Based Training Overview

As its name implies, computer based training is simply using the computers to provide training. The multimedia capabilities of modern personal computers allow CBTs to provide engaging and effective training. This is especially important with younger trainees who have grown-up in the personal computer age and expect extensive multi-media presentations. CBTs have many advantages and some disadvantages (Table-1). One of the most important criteria for a successful CBT is to select an appropriate topic. CBTs are most appropriate under any of five main conditions: 1) large numbers of trainees need training now or over an extended time, 2) trainees are not readily available due to geographic location or shift work, 3) the activity being trained is very important, 4) the material doesn't change frequently, and/or 5) human trainers are not readily available.

TABLE-1. General CBT Advantages/Disadvantages

ADVANTAGES	DISADVANTAGES
Repeatable Training	Initial High Dollar Cost *
Standardized Training	Less Personal Interaction
Self Paced Training	Initial Large Investment Of Experts' Time *
Interactive Training	Requires More Trainee Initiative / Responsibility
Training Available On Demand At Any Time	Large Design Effort Needed For Effective CBT
Private Training (no embarrassment in asking questions)	Some People Hesitant To Use Computers
Some People Prefer Using Computers	Experts May Feel Threatened
Immediate Test Feedback	
Multimedia Activates Diverse Learning Styles	
Instructors And Experts Freed For Other Duties	
Better Use Of Slow Times (night shifts, weekends, etc.)	
Local And External Expertise Documented Permanently	
Eases Tracking Of Training Shortfalls, By Trainee & Organization	
Remote Delivery	

2.2 BOLT Design Features

BOLT was designed using Air Force Instruction Systems Design (AFM 36-2234, 1993). Throughout the process, the designers remained focused on the primary target trainees of newly assigned enlisted forecasters. BOLT is sent to in-bound 45 WS personnel, allowing them to learn about the 45 WS mission and the importance of lightning, and pre-train before arrival to achieve certification faster. BOLT also has other uses and other users (Table-2).

Most people learn best through one of three major learning styles: visual, aural, or kinesthetic. Effective training of large diverse trainee populations requires activating all three learning styles simultaneously as much as possible. Interactivity is important to keep the trainee involved. Even an individual benefits from the activation of all styles. Even with a primary learning style, they still learn to some degree through the other styles. Computer based training makes heavy use of the visual learning style through extensive use of the visual aids, especially animation. The aural learning style is also heavily activated through wide use of recorded narration. An even mix of both male and female voices was used for better training of both genders. The kinesthetic style is tougher to activate in CBTs. But BOLT's 'exploration paradigm', moving the mouse over screen objects to "pop-up" instruction, is somewhat kinesthetic.

BOLT was designed to both supplement initial certification training of new forecasters, led by a trainer, and annual recertification training, often done via self-training with independent testing. Thus, BOLT was designed to be used both under instructor-led training and as stand-alone training.

TABLE-2. BOLT Applications (in priority order)

PRIMARY TRAINING USE
Initial Training of Enlisted Forecasters Pre-training of Enlisted Forecasters Before Arrival
SECONDARY TRAINING USE
Recurring Training of Enlisted Forecasters
Initial Training of Launch Weather Officers
Recurring Training of Launch Weather Officers
OTHER USES
Training of Researchers Working on 45 WS Projects
Orientation of Visitors to CCAFS/KSC
Demonstrations of BOLT

A very pragmatic design issue is maximizing the use of more costly advanced CBT options while staying within the budget. The design team chose expensive 3-D animations only for items that could be reused often throughout BOLT. For example, a 3-D animation is used to teach the five main components of a cloud-to-ground lightning flash. That same 3-D animation is reused in the various lessons on lightning sensors, showing how they locate different parts of lightning.

Each lesson in BOLT ends with a section listing external HTML links. These links are supplemental papers, briefings, or websites. As the lightning systems or forecast techniques evolve, 'change notices' can be posted here too. Since these simple HTML links are on a network drive, external to the BOLT software, 45 WS can easily edit them. This is a much more cost-effective method of maintaining a CBT, which otherwise requires the contractor doing more programming or the unit personnel learning complex CBT-authoring software.

Considerable effort was invested in the test design. In a deviation from pure Air Force Instructional System Design, the emphasis on question design was to reinforce the trainee's learning, as opposed to measuring trainee learning. In simple CBTs, questions are usually just 'True & False' and 'Multiple-Choice', since they are easy to automate. However, BOLT also included 'Matching' (Fig. 2) and 'Fill In The Blank' questions (example not provided). Automating these latter two types of questions, and their grading, is much tougher than the other types of questions. But the designers strongly believe that diversity of question types reduces boredom and facilitates learning. The design of the question feedback function has proven surprisingly successful and popular (Fig. 3). Immediately after completing a quiz at the end of a lesson, or the final exam, the score is displayed, along with a 'feedback square' for each question. The 'feedback' square is either colored 'green' or 'red' depending if that question was answered correctly or incorrectly, respectively. Remediation (correction of errors and retraining) is provided by clicking on the 'red' 'feedback squares'. The question is redisplayed with the trainee's incorrect answer and the correct answer both highlighted. If the trainee still doesn't understand the correct answer, a second level of remediation is available by a button that takes the trainee directly back to the appropriate part of the lesson. The feedback page of the final exam can be printed to document successful completion of the CBT. Problem areas can be retrained by an instructor.

The professionally designed graphics/animations in BOLT were also provided as stand-alone files in standard file formats like JPEG. Thus 45 WS can get double-duty from these files by using them to construct independent briefings, such as by inserting them into PowerPoint.

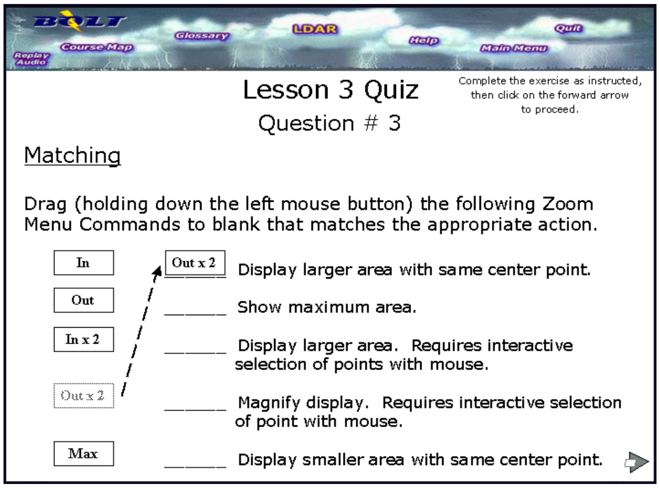


Figure 2. Example of Matching question. The arrow indicates the mouse click & drag action done to answer the question. This type of question is rare in small CBTs.

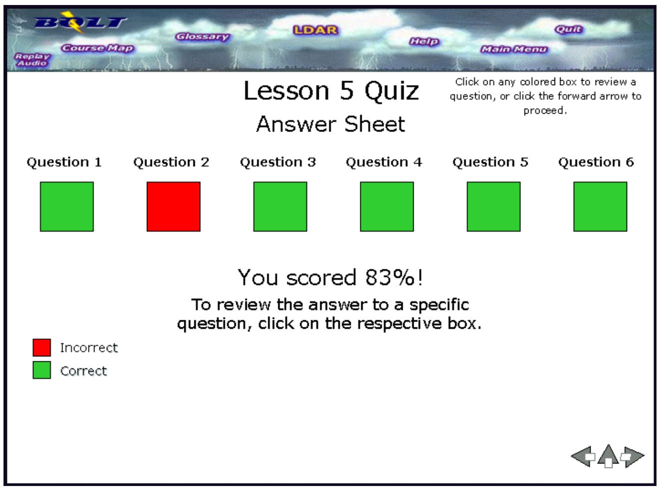


Figure 3. Example of the quiz/final exam performance feedback screen. Two levels of remediation are provided.

2.3 BOLT Structure

BOLT consists of eight lessons, a comprehensive final exam, and several support modules (Table-3). The lessons are meant to be followed sequentially, especially for first-time trainees. But they may also be run as stand-alone lessons, in any sequence for refresher training. Even sub-sections of lessons may be reviewed independently.

Lesson #1 is a basic overview of the 45 WS mission, with special emphasis on the importance of lightning. The 45 WS lightning advisory process and the special lightning sensors used by 45 WS are also introduced.

Lesson #2 illustrates basic lightning mechanics, especially the parts of a lightning flash detected by the 45 WS lightning sensors. Lightning from cellular thunderstorms is emphasized. Lightning from anvil clouds and debris clouds is also included, since those can cause surprisingly long-distance or long-delayed lightning from the parent thunderstorm, respectively.

TABLE-3. BOLT Lessons And Support Modules.

NO.	**LESSON**
1	45 WS Mission Overview
2	Lightning Mechanics
3	Lightning Detection And Ranging System
4	Cloud-Ground Lightning Surveillance System
5	Launch Pad Lightning Warning System
6	North American Lightning Detection Network
7	45 WS Lightning Forecast Techniques
8	Data Integration
SUPPORT MODULES	
	Final Exam
	BOLT Orientation
	Glossary
	Help
	Course Map (jump directly to anywhere in BOLT)

Lessons #3 through #6 teach the lightning detection systems. Each of these lessons has the same structure. This consistency enhances learning and facilitates finding specific sub-topics later. The first section is the 'System Overview', which discusses applications, sensor components and locations, operating principles, and strengths and weaknesses. Next is 'Interface Familiarization', which teaches the "knobology" of how to operate the system. The 'Frequently Used Procedures' trains the basic day-to-day uses of the systems, to get the trainee up to minimum operating capability as soon as possible. The 'Data Interpretation' section teaches how to apply the data in lightning forecasting. Finally, a short quiz is provided.

Lesson #3 teaches the Lightning Detection And Ranging (LDAR) system, invented by KSC. LDAR is a unique system that locates stepped leaders from all types of lightning to depict the full three-dimensional structure of lightning flashes and to trace total lightning activity over time.

Lesson #4 teaches the Cloud-to-Ground Lightning Surveillance System (CGLSS). CGLSS is a local network of six cloud-to-ground lightning return stroke detectors using the Improved Accuracy through Combined Technology (IMPACT) sensors (Cummins, et al., 1998). BOLT uses a series of animations to teach the two techniques used by IMPACT to locate CG-Lightning return strokes (Fig. 4). CGLSS is used to evaluate the need to retest electronics in rockets and payloads for EMP damage, and to help issue and verify lightning advisories.

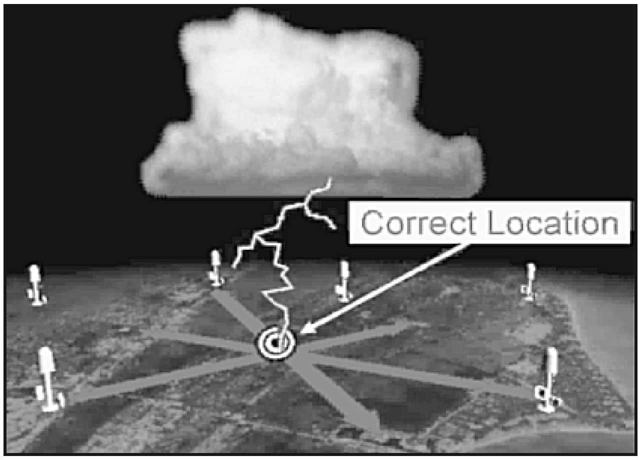
Lesson #5 teaches the Launch Pad Lightning Warning System (LPLWS), a local network of 31 surface electric field mills. LPLWS is used to detect the initial electrification of developing thunderstorms and detect electrification in anvil and debris clouds. This system is used primarily to help evaluate the Lightning Launch Commit Criteria. LPLWS also has a limited capability to locate all types of lightning.

Lesson #6 teaches the North American Lightning Detection Network (NALDN) (Cummins, et al., 1999). NALDN is used by 45 WS as a back-up to the local lightning detection systems, to provide lightning information on approaching weather systems outside the range of the local detectors, and to support off-site weather missions.

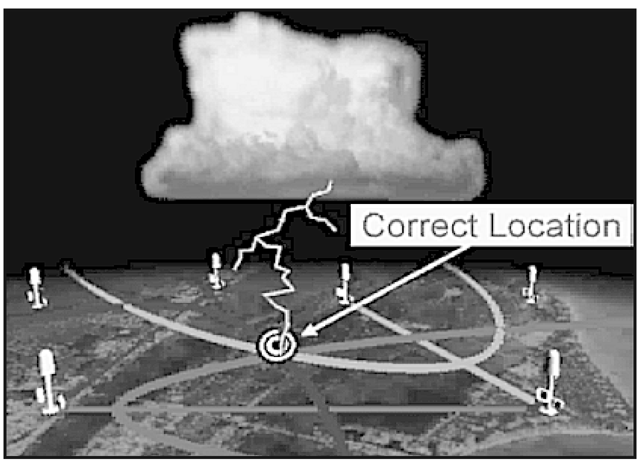
Lesson #7 teaches 45 WS techniques for radar lightning forecasting (Roeder and Pinder, 1996). These techniques show how to forecast lightning from thunderstorms, anvil clouds, and debris clouds. A short quiz is provided.

Lesson #8 is 'Data Integration' and details how to integrate all the lightning sensor data and forecast rules to issue lightning advisories. A short quiz is provided.

BOLT concludes with a comprehensive final exam covering all eight lessons. This exam consists of 30 questions, none repeating the questions from the quizzes at the end of the individual lessons.



a) Direction-Finding locating of CG-lightning return stroke.



b) Time-Of-Arrival locating of a CG-lightning return stroke.

Figure 4. Two still pictures from the BOLT animation showing how CGLSS locates a CG-lightning return stroke.

2.4 BOLT Future Upgrades

Software development invariably has mistakes in the "final" program. The designers allowed 10% of the total budget for maintenance after the initial delivery. The initial delivery was extensively debugged before acceptance, so most of the maintenance budget was used for upgrades.

Several design features were sacrificed to stay within budget. 'Advanced Procedures' would have fully explored all the capabilities available from each of the lightning sensors. At present, only a basic initial operating capability is taught.

'Simulators' would have interactive displays in which the trainee can operate the simulated lightning sensors and they would react as they would in reality. 'Exercises' would allow the trainee to modify simple schematic weather and the sensors react appropriately. One exercise could include a constant thunderstorm that is moved toward or away from the suite of sensors. Or the trainee could adjust the reflectivity pattern in a stationary convective cell. Other exercises could adjust the advection of an anvil cloud, or the evolution of debris cloud over the sensor networks. 'Simulators' and 'Exercises' are a good way to increase the activation of the kinesthetic learning style.

Scenarios demonstrate how the thunderstorms evolve using real world data from important recurring weather patterns in central Florida. New scenarios might include: southwest gradient flow, squall line approaching from the northeast, thunderstorm cessation, anvil cloud approach and dissipation, and debris cloud development and dissipation.

Several important topics had to be omitted. These included some local thunderstorm and lightning forecasting techniques, the flow-regime stratified lightning climatology for Florida and the 45 WS lightning advisory areas (Lericos, et al., 2002), and the lightning detection capability of LPWS.

Another desired feature is to use 'question banks' from which different quizzes and final exam would be randomly generated. At present, the same quizzes and final exam are used every time. Each 'question bank' would hold several different questions all testing the same concept. Mandatory 'banks' would ensure vital concepts are always tested. Randomly generated tests would decrease boredom in repeating BOLT and avoid trainees memorizing the answers.

Automatic long-term 'test tracking' would also be useful. BOLT would flag questions with suspect performance, which the training managers would analyze to see if the questions were poorly worded, the instruction needs improvement, of if the flag was a statistical fluke.

3. SUMMARY

The 45 WS recently implemented computer based training for basic orientation and lightning training. Lightning prediction is a vital skill needed by forecasters to support the intensive lighting advisory requirements at 45 WS. The 45 WS has the densest suite of lightning sensors in operational meteorology, some of which are unique. New enlisted forecasters are typically not well trained in lightning forecasting or in the use of the 45 WS lightning sensors. The BOLT CBT was implemented to improve training in issuing lightning advisories for America's space program.

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