APPLICATION OF COMPUTER-BASED TRAINING FOR IMPROVED MAINTENANCE TRAINING EFFICIENCY

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It is an honor for me to be here to speak about improving some aspects of maintenance training by applying computer-based training. Let me begin by stating a few facts. We all know that today the air transport industry is facing a major crisis. Since the demand for available seat miles is less than the supply, aircraft are being deactivated. Since airlines are losing money, airline workers are being laid off. Here in the U.S., airlines are operating under Chapter 11 or are going bankrupt. So, this obviously would not seem to be the right time to brood about new training concepts.

However, you may be interested to note that *crisis* is derived from ancient Greek and originally had two seemingly different meanings. The familiar meaning points to an unstable, dangerous situation; the second, strangely enough, points to a chance or opportunity. In the case of the air transport industry, the chance should be viewed in terms of consequences of the pressure on airlines to become more efficient. The issue is so serious that airlines which do not become more efficient will not survive. The chance the current crisis offers is for airlines to use the excess human resources many of them have these days to realize their current strategic goals and to be better prepared for the future. Well- prepared, efficient airlines can meet their future earning goals with their marketing, reservations systems, service systems, and so forth. Efficiency also positively affects costs.

Figure 1 shows the typical cost distribution of a typical airline. Incidentally, the figures are from Boeing. These figures are from Boeing's current market data, and they use them every year. There are only a few costs we can influence. Costs like those for fuel and landing fees cannot be greatly influenced by an airline. However, the 11.5% of total costs for maintenance can be positively influenced. Given that the overall operational profit margin of an airline over the last two decades or so is typically 2%, you can imagine how much we can improve profits by reducing maintenance costs.

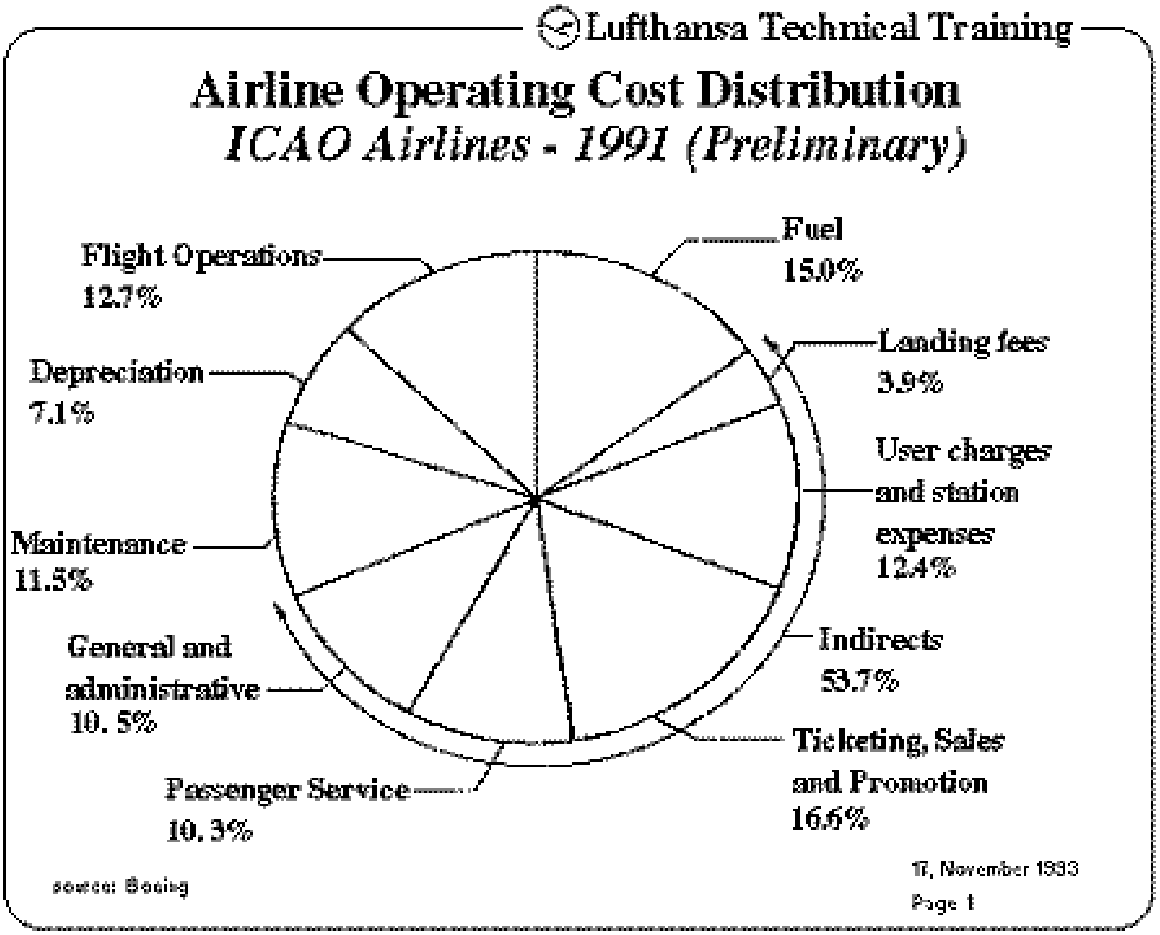

Figure 1

We should also continuously assess the present situation and anticipate future developments. One parameter we are interested in, obviously, is our future capacity requirement (Figure 2). These figures, again, are from Boeing's current market outlook. Notice that the almost- catastrophic crisis, or at least the crisis that was a catastrophe for a few airlines, shows as only a small dip in the capacity requirement. Even though we as an industry are certainly facing difficult times, there is no doubt whatsoever that the capacity requirement will reach levels much more dramatic than many people realize.

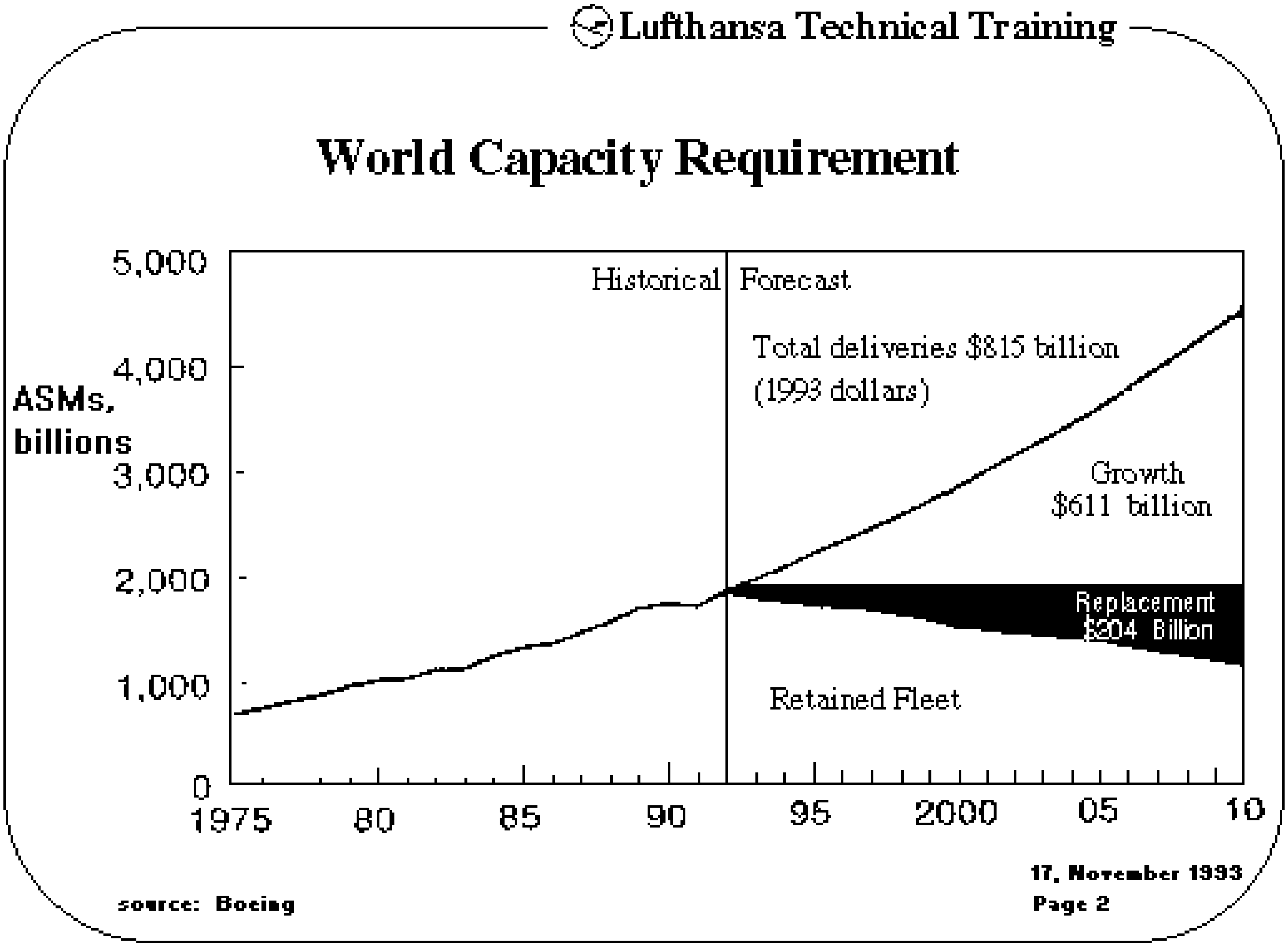

Figure 2

Next, consider U.S. airlines operating profit margins (**Figure 3**). The gray areas represent recessions when profits are, of course, unstable. The average profit margin is 2%, but there are major noise factors leading to losses during recessions. The industry either has just been through or is still in a recession now. Boeing is expecting a profit margin between 4% and 6% after 1995. Boeing has been undertaking this study for about 20 years, and they have been very successful in anticipating the future. After all, they are number one in the aircraft industry. While we can somewhat rely on their numbers, we also have to realize profitability is certainly not guaranteed for airlines because Boeing thinks the good times will return when airlines can charge passengers at pleasure in order to cover their costs and provide some profit margin. In any case, money will certainly not be falling from the sky. Rather, the only airlines to survive are the most efficient in providing air transport service.

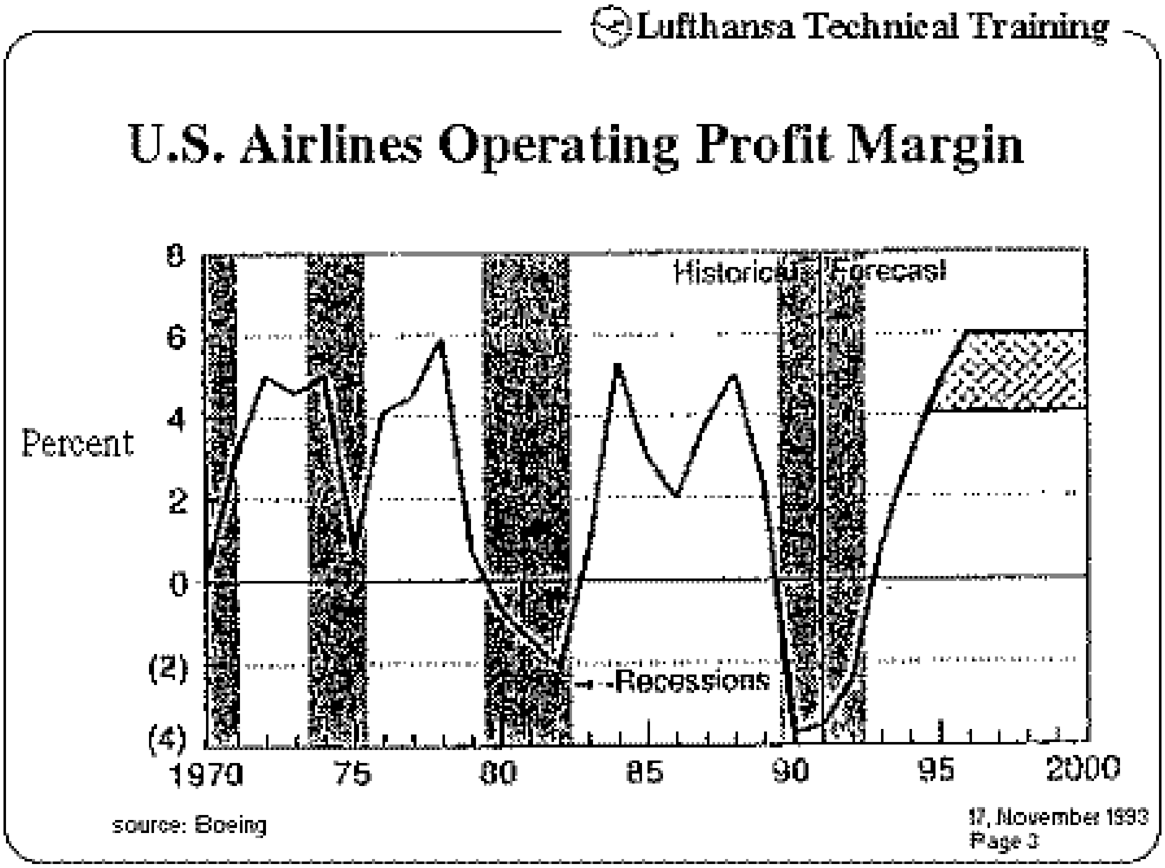

Figure 3

As an example of this increased efficiency, the Boeing study simply assumes a 3.9% per year decline in maintenance costs. Maintenance clearly has to become more efficient to meet the challenges of tomorrow's air transport environment. How can we enhance maintenance efficiency (**Table 1**)? One way certainly is to purchase maintenance-friendly aircraft. There has been a lot of progress in this direction, and today's aircraft are much more maintenance- friendly. We are not going to talk about this today. Once an aircraft is in operation, of course, the task is to optimize the maintenance schedule, maintenance organization, and work structures. We heard a bit about this from the last speaker. I would like to address a third issue: qualifying maintenance staff exactly to the required competence. Before we do that, we should realize a few facts and conditions that, in my opinion, sum up the problem statement (Table 2).

Table 1 Ways to Enhance Maintenance Efficiency

- Design/Purchase Maintenance-friendly Aircraft
- Optimize Maintenance Schedule, Maintenance Organization, Work Structures
- Qualify Maintenance Staff exactly to Required Competence

Table 2 Facts to Sum up the Problem

- Aircraft technology increasingly complex
- Maintenance training volume steadily increasing
- Yet: Training results increasingly questionable
- Benefits of aircraft technology advances not fully realized in maintenance
- Presently: Qualified maintenance personnel decreasing/migrating to other professions
- After 1995: Over-proportionally increasing demand for AMTs

First, everyone knows that aircraft technology is becoming increasingly complex and will continue to become even more complex. The amount of training maintenance requires is concurrently increasing steadily, or at least the volume has been steadily increasing. The problem we now have is that training results are increasingly questionable. While an AMT may have passed an examination, we are not really sure that he or she is really competent to locate a fault when seeing only its symptom. We also wonder if an AMT is competent to use the aircraft documentation or the troubleshooting manual. In short, we have questions as to whether the AMT is actually fully trained for his or her tasks. I certainly doubt that he or she is.

The benefits of technological advances in aircraft are not fully realized in maintenance. Many training and maintenance structures do not fully benefit from the fact that we have fault- tolerant aircraft capable of surviving multiple faults without having to be repaired. The CMC (Central Maintenance Computer) or CFDS (Central Fault Display System), if you will the troubleshooting computers, are not fully utilized as the prime tool for many concepts. Also, maintenance personnel are migrating into other professions simply because they are being laid off. However, the Boeing study and the Blue Ribbon report, mentioned earlier today, predict an increasing demand for AMTs after 1995. Now, I am not saying we were not prepared to produce competent AMT's in the past; and I am also not saying that we can throw away anything that we have learned about training. I am saying that we are going to have a problem tomorrow if we do not anticipate future demands and challenges today.

We cannot simply continue to address training the way we have in the past. Today, we have to embark into developing and implementing more efficient training strategies (**Table 3**). This effort is twofold. First, we have to produce the required number of competent AMT's after 1995; second, we have to synchronize AMTs' skills with technology changes efficiently. Therefore, we have to ask ourselves what are we doing wrong (**Table 4**) and identify what will we have to do to be better in the future. This process is not confined to Lufthansa, to European, or to U. S. airlines. It is a typical challenge, I would say, for the entire world.

Table 3 The Challenge

To embark into more efficient Training Strategies:

- To produce the required numbers of competent AMTs after 1995
- To efficiently synchronize AMTs' skills with technology changes

Table 4 What are We Doing Wrong?

- Apprentice Training based on yesterday's technology
- Skill deficiencies only partially compensated by lengthy Type Rating Courses
- Hopeless attempts to mediate increasingly complex technology by increasing training volume

Yet: AMTs are not sufficiently prepared for their task
Yet: Aircraft safety essentials sometimes falling a victim to aircraft complexity

Apprentice training for AMTs is typically based on yesterday's technology. I think that the Blue Ribbon Panel pointed out that while some five or so AMT schools were updating their training, they still rely upon yesterday's technologies such as prop airplanes, avionics, and software. These AMTs will have skill deficiencies once they enter airline operations, and these deficiencies are only partially compensated by lengthy type rating courses. Eventually, airlines get caught in what are essentially hopeless attempts to mediate increasingly complex technology with increased training volume.

We have to realize that with a typical modern aircraft there are some 20,000 signals being processed, transmitted and received. It is completely hopeless to attempt to explain everything. The trainers, at least those designing the curriculum, basically try to include what is probably necessary to know and also include what has to be addressed in order at least to address an airplane's most important features. The result, at least at Lufthansa, is that a modern aircraft such as a 747-400 has a thirteen weeks' type rating course, which is too much. An average of 10% of our mechanics are constantly in training, which is also too much. The problem is compounded by the fact that, as I indicated above, AMTs are not fully prepared when they join an airline's operations.

Even more marginal, to say the least, aircraft safety essentials sometimes fall victim to an aircraft's complexity. In the mess of all the various functions and signals, in the middle of all the thousand of things that seem to be somewhat important, essentials suddenly get lost. Let me give you an example. A mechanic has typically been trained to and fro, forwards and backwards on the autopilot. He or she also knows all the logics and subroutines one finds in a computer nowadays (to me, by the way, that knowledge is a complete nuisance). However, suddenly it happens, in fact it happened in my airline, that there was a squawk and the dual autopilot disconnected below 100 feet. There are so many squawks on autopilots, so much nuisance, that the mechanic did not understand, "Hey, this is something else. It has a different dimension. There must never be an autopilot disconnect below 100 feet. A dual-land operation on an autopilot is not supposed to do that." Consequently, this problem was treated like many other squawks; it popped up to somebody who thought, "Hey, we have a problem here. This autopilot has a design deficiency." This is a typical example of why the aircraft essentials are important; it is not so critical to have all the functions in memory.

What can we do to solve our training problem (Table 5)? Mechanics certainly need more profound jet aircraft fundamentals training, as for example that provided by the TRO/DLH CBT project on JAMF (Jet Aircraft Maintenance Fundamentals). This project arose from our conviction to meet future AMT requirements in both quantity and quality. Mechanics need a profound base of know-how about modern jet aircraft. When a mechanic is familiar with the generic systems of a modern aircraft, the peculiarities of a specific aircraft type are not so problematic. Task-oriented type rating training, such as the new DLH concept on type rating discussed later, can then be extremely efficient.

Table 5 The Solution

- Profound Jet Aircraft Fundamentals Training
  Example: TRO/DLH CBT-Project on "JAMF" (Jet Aircraft Maintenance Fundamentals)
- Task Oriented Type Rating Training
  Example: New DLH Training Concept on Type Rating

Let me enlarge a bit on JAMF, a project we are working on as a part of our fundamentals training and CBT project (**Table 6**). We are working with TRO (TRO Learning, Inc.) on this project. Although it costs a lot, we believe this is our best way to create a platform to work with in the future.

Table 6 JAMF Project

The Target Population

- A&P apprentices
- Skilled workers of appropriate technical trades, like car mechanics, to be re-trained to A&P mechanics in large jet aircraft maintenance
- A&P licensed mechanics with no experience in latest generation large jet aircraft maintenance

The Concept

- Task/procedure-based instead of system-based approach to determine the training contents
- Up-to-date aircraft technology (747-400/A320 generation)
- Edutainment
- Computer-based training (CBT, 100 hours of courseware); Classroom training; On the job training (OJT)
- Latest CBT technology, video overlay

JAMF's target population is primarily A&P apprentices from schools and colleges who have little experience in any trade. Also, we are targeting skilled workers in appropriate technical trades like auto mechanics who can be retrained as A&P mechanics in large jet aircraft maintenance. Licensed mechanics without experience working on modern jet aircraft are also included.

JAMF uses a task/procedure-based approach, not a system-based approach, to determine training contents. I will get back to this later. JAMF uses up-to-date aircraft technology, i.e. the 747-400 and the A320 as the generic aircraft. We included at least long-range, short- range, two-engine, four-engine, and the current generation. One thing we find very important is the edutainment value we insert in the program. In other words, a mechanic must be thrilled to go through this training. A mechanic should never say, "Thank God it's Friday"; we want him or her to say, "What a pity the day is over."

JAMF includes some computer-based training, using essentially the latest CBT technology with the video overlay. In other words, there is one screen containing the CBT and video. Of course, we also have both classroom training and on-the-job training, depending upon the lesson's content.

The major, and probably the most important, part of JAMF is the process of identifying the current training needs. Let me briefly describe it. In the top left of **Figure 4**, there is the terminal task listing. What we do is to go through all the job cards for the 747-400 and the A320 and also analyze the target population, e.g. what knowledge do our students have and what knowledge do we have to give them. These elements together comprise the Task Procedure Analysis: this is the point where we select and generalize so-called concepts. A *concept* is an idea, comprehension, or conception in aircraft technology that is not commonly known from daily life. The concepts are then sorted into a concept hierarchy from superordinant to subordinant. For example, a superordinant concept would be electrical power system; a subordinant, the DC power system, emergency plus battery. The concept hierarchy ensures that concepts are complete, that no important concept is missing simply because it did not appear on a job card for at least one aircraft.

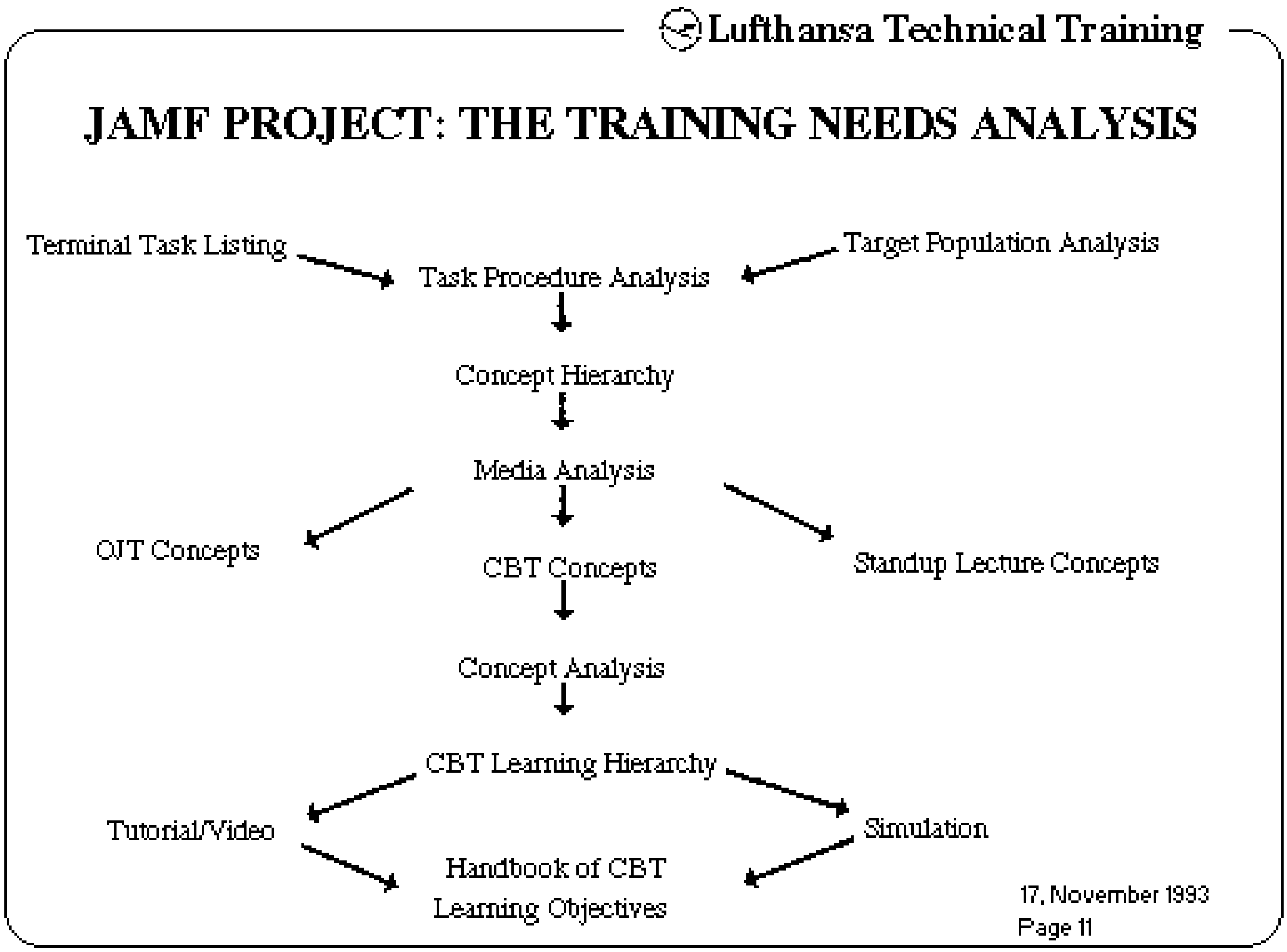

Figure 4

Concepts are then sorted as to which kind of training method or media is appropriate. The best approach for training may be on-the-job, CBT, or a standup lecture. For the project with T.R.O., we are picking out and making a concept analysis only for the CBT concepts. We are trying to determine the concept's peculiarity, its purpose, why it is necessary, and how it is best accomplished.

The next step is to define the learning sequence in the CBT learning hierarchy. Of course, this consists of tutorials and videos, being more-or-less an explanation for the student, and the simulation, being an exercise. Eventually, we chunk everything together. We allocate time and eventually create lessons from these elements. The result is a handbook of learning objectives.

The course menu is straightforward. As shown in **Figure 5**, there are unit menus containing tutorials and simulations. There is a glossary which the student can always access to find out the specific meaning of a word or abbreviation. There are questionnaires at the end of each section, and there is a final mastery test. Now, I would like to elaborate on a few aspects on this project.

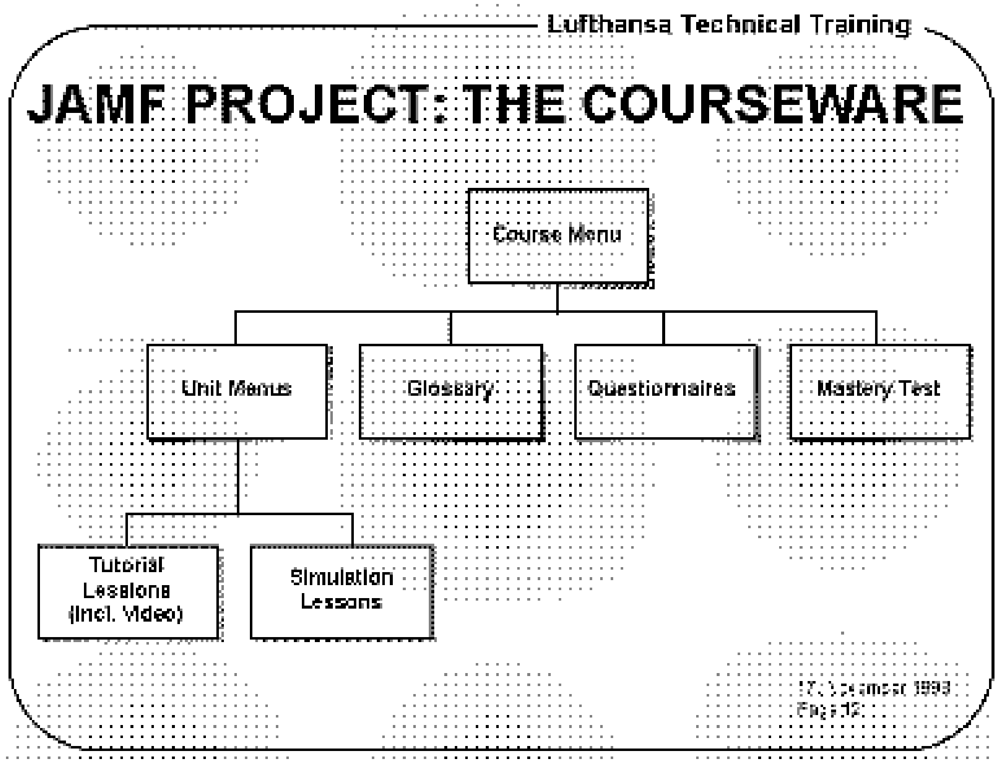

Figure 5

As I mentioned, not all training objectives are best met with CBT. Standup lectures are and will continue to be necessary. Certainly, on-the-job training is always necessary; things like a torque on a bolt cannot really be trained because an AMT has to feel it. CBT is best used for system- simulation arrangements. This is the major advantage and strength of CBT. In order for the student to master certain systems, system operation, and troubleshooting certain things, in other words for the student to learn by doing, CBT is also for tutorials designed to meet these objectives. We intend to have students use CBT without a trainer being present, but this is only possible and acceptable when designers take a systematic approach. In other words, we have to use a lot of manpower to arrive at a CBT lesson that provides a good tutorial that is acceptable to the student. Tutorials cannot be made on the basis of substituting standup lecture point-by-point and claiming that you now have a CBT tutorial. This has been done in the past quite often, leading, in my opinion, to unacceptable, catastrophic results.

As I said, type rating is training in fundamentals. I would now like to talk a little about the courses we have for type rating. CBT in this case is applied to simulation models. Since students actively use simulation modules, they appear to be very valuable. However, if they are done right, tutorials turn out to be too expensive. Therefore, we had to change our thinking about training for the type ratings concepts.

Our incentive for the new DLH concept on type rating courses was that we wanted to benefit from maintenance fundamentals training and avoid tedious repetitions (**Table 7**). For example, an hydraulic actuator was again and again explained in each type rating course. This ridiculous nuisance was necessary simply because it was not included in fundamental training. We now use task-oriented training to avoid training complex and unnecessary ballast such as the autopilot interlock chains.

Table 7 Incentives for New DLH Concept on Type Rating

- Benefit from profound Maintenance Fundamentals Training - Avoid tedious repetitions
- Task Oriented to avoid training complex, unnecessary ballast
- To make use of modern jet aircraft maintenance tools
- To maximize mechanics' competence on their jobs
- To maximize safety and economical benefit of training - using most efficient training methods and media

We also want our mechanics to use all the available maintenance tools. Our goals are to maximize mechanics' on-the-job competence to do the work they are required to do, to train them to use EDP (Electronic Data Processing) terminals, to train them to use aircraft documentation, and for them to learn to do those tasks they have not been trained on earlier. Eventually, to maximize the safety and the economic benefits of training, we do not want 10% of our mechanics in training.

I would like to briefly address subject-oriented as opposed to task-oriented training (**Figure 6**). In the past, we in the airline industry have utilized subject-oriented training. In other words, we have explained the aircraft, more or less in the hope that the mechanic would be able to handle the aircraft and perform necessary tasks once he or she understood all the functions. As you can see in the figure, of all potential training objectives, the results subject-oriented training achieves (vertical ellipse) are not the same as desired training objectives (horizontal ellipse). Subject-oriented training includes areas in which desired training objectives are achieved, but there are also desired training objectives that are not achieved. Subject-oriented training also achieves undesired training objectives, typically those things never exercised in the field. These are the things that people vaguely remember having heard five years ago. Desired training objectives are not things students learn only for an examination and never use again. Subject-oriented training leads to both "not achieved" and "not desired" training results. We are now trying to structure training so that desired and achieved training objectives are identical.

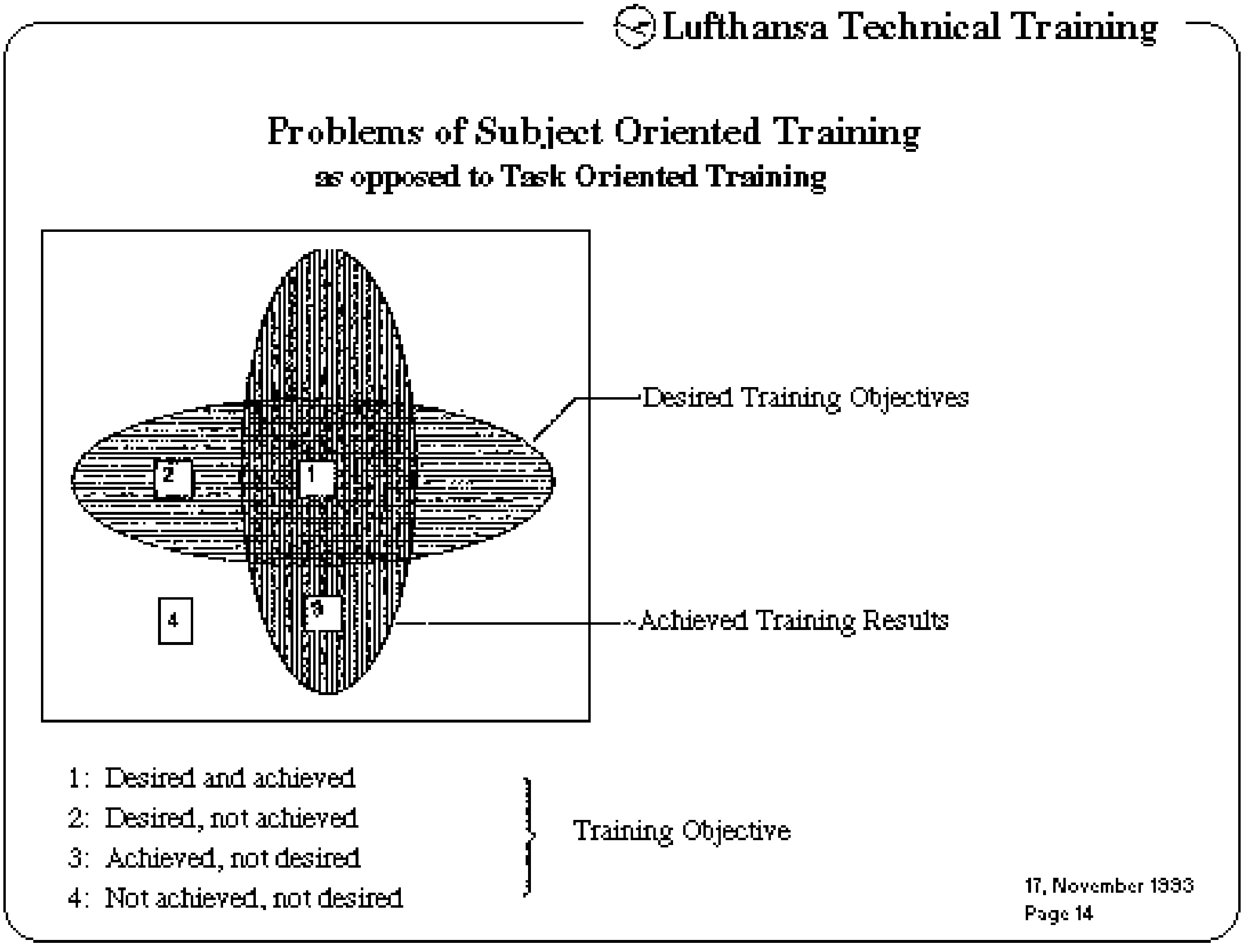

Figure 6

The training preparation sequence (**Table 8**) for the new DLH concept on type rating begins with the task analysis, i.e. with taking all job cards and identifying the qualification level (skills) a mechanic must have to perform the task. For example, a job card could contains the necessary steps for activating the APU. The next step is the training objective analysis, e.g. to identify what a student needs to activate the APU. Next, the trainer has to determine training steps and pick the most efficient training method and aid for each training step. The end result is a curriculum definition.

Table 8 Training Preparation Sequence for New DLH Concept on Type Rating

- Task Analysis
  for specific aircraft type
- Training Objective Analysis
  depending on qualification level required
- Determination of Training Steps
- Selection of most efficient training Method and Aid for each Training Step
- Curriculum Definition

Some training methods and aids are summarized in **Table 9**. Although CBT plays a major role in our training, we certainly do not use it exclusively. We continue to have standup lectures for tutorials, as well as instructor-led CBT's for tutorials. This is very nice, by the way. It provides more or less a moving overhead foil that can help students visualize signal flows and switchings. We have student-paced CBT mainly for exercises. We also use a full flight simulator, although we unfortunately do not have a maintenance simulator. Since a full flight simulator is so expensive to use, we employ it for circumstances such as engine run-up training. This allows us to avoid having an aircraft standing outside and having to train outside.

Table 9 Training Methods and Aids for New DLH Concept on Type Rating

▪ Stand-up Lesson	(e.g. Tutorial)
▪ Instructor-led CBT	(e.g. Tutorial)
▪ Student-paced CBT	(e.g. Exercise)
▪ Full Flight Simulator	(e.g. Engine Run-up)
▪ Team Exercises	(e.g. Troubleshooting with A/C DOC)
▪ Video	(e.g. Location)
▪ On-the-Job	(e.g. Removal/Installation)

We also use team exercises. For example, we might have four students sit together and train troubleshooting. The students would have access to the aircraft documentation. We also use video for location training, and of course we have on-the-job training like taking the students to an aircraft and performing tasks such as removal/installation. We try to mix method and media; we think this is necessary in order to keep the students awake. Quite frankly, thirteen weeks in the classroom from morning to afternoon can be quite tedious.

I would like to conclude my presentation with a few messages to the U.S. as well as the European airline industry. We must find ways to be efficient and part of that is to bring our technicians to the necessary competence and to ensure unimpaired flight safety as a result. Since our salaries in the Western world are magnitudes higher than in other countries, we cannot afford to have students sit in a classroom and fight against falling asleep. We also cannot afford to keep an aircraft on the ground because our AMTs are not competent to release it for service. We must make the maximum benefit of our human resources to secure our place in the world's leading aviation industry countries.