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ADP010999

TITLE: Lessons Learned During the Development of the Modular Lightweight Load-Carrying Equipment [MOLLE] System

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TITLE: Soldier Mobility: Innovations in Load Carriage System Design and Evaluation [la Mobilite du combattant: innovations dans la conception et l'evaluation des gilets d'intervention]

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ADP010987 thru ADP011009

Lessons Learned During the Development of the Modular Lightweight Load-Carrying Equipment (MOLLE) System

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Summary

The US Army conducted a comprehensive front-end analysis (FEA) which surveyed key users and identified critical issues and requirements for developing new load bearing equipment (LBE). From the FEA a detailed users' operational requirements document (ORD) was developed and from both the FEA and ORD the MOLLE emerged. The results of these efforts reveal several things about the methods used, as well as, issues and features of the system developed. This paper discusses the lessons learned about test methodology and features of LBEs found to work or not work for the dismounted combatant.

Introduction

In 1988, a new internal frame, load-carrying system was adopted by the U.S. Army. The design was based on commercial backpacks modified for military use with the addition of a special fighting vest and a detachable patrol pack. The original focus was to develop a load-carrying system for use in cold weather. However, in the final analysis, the US Army selected the new internal frame LBE as a replacement for the external framed All-purpose Lightweight Individual Carrying Equipment or ALICE system. Production and distribution started in 1990 but by 1993 it was clearly evident that the new internal frame pack was unacceptable to a large number of combat personnel.

Although a key problem with the internal frame was durability due to poor quality control in production, it was also judged to have basic design flaws. Based on a survey of users by the US Army Training and Doctrine Command (TRADOC), soldiers claimed the pack was too hot against the back in warm climates, and was unstable and uncomfortable when heavily loaded. While many of the features of the system were liked (e.g., the patrol pack, and capacity of the main pack), it was judged not to meet the overall requirements of the Army. In spite of this rejection, most units surveyed (6 of 9), still favored having both load-carrying systems: the ALICE for warm and temperate climates, and the internal frame system for cold weather operations. This was not to be.

In March 1994, the TRADOC System Manager for the Soldier (TSM-Soldier), the Combat Developer at the U.S. Army Infantry School, the Program Manager (PM)-Soldier, and the U.S. Marine Corps Systems Command, called for a front-end analysis (FEA). The FEA was to determine what the Army and Marine Corps load bearing system design should be (ref. 1). The FEA was used in drafting a new user requirement document and initiating the development of a modular load-carrying system that ultimately became the Modular Lightweight Load-carrying Equipment (MOLLE).

This paper presents summaries of the FEA survey and the results from the subsequent series of tests conducted during MOLLE development. While test methodology is presented, the main focus is on addressing and identifying important features of load-bearing equipment important to infantrymen. This is followed by discussion as to why engineering efforts continued on retaining certain features, in spite of the fact tests showed these features were not performing well and were not universally accepted by users.

Paper presented at the RTO HFM Specialists' Meeting on "Soldier Mobility: Innovations in Load Carriage System Design and Evaluation", held in Kingston, Canada, 27-29 June 2000, and published in RTO MP-056.

Approach

For the FEA, a user questionnaire and a group interview form were developed from statements collected from soldiers and marines as well as from information obtained from the 1988 technology demonstration on Lightening the Soldier's Load (ref. 2). Questionnaire items asked about the type of LBE in current use, types of problems encountered and solicited recommendations for improving LBEs. A small pilot test was run to refine wording of the questions and statements. Questionnaire items were pre-structured statements based on all the issues identified and were either numerically scaled 0 to 4 (None to A Lot), verbally scaled Strongly Agree to Strongly Disagree or merely check-off lists of items or issues. At the end of the questionnaire respondents were asked to write down any suggestions they had for improvements. The final questionnaire was used as a framework for the user-focus-groups referred to here as "muddy boot" teams.

Over a period of seven months questionnaires were distributed to over 2,000 soldiers and marines by U.S. Army Natick Operational Forces Group during their routine surveys of users of Natick developed food, clothing, shelters, and individual equipment items. Five US Army posts (Forts Bragg, Campbell, Drum, Hood and Lewis) and two US Marine Corps sites (Camps Mabry and Lejeune) were visited. All those surveyed had experience with the ALICE and 40 percent also had experience with the recently introduced internal frame system. Highlights of the results are presented below. In addition, results from a series of eight developmental tests (unpublished) on MOLLE are presented. These tests involved experienced soldiers who evaluated candidate systems during simulated tactical movements in the field and laboratory.

For the developmental tests, a series of short but comprehensive human factors (HF) questionnaires was developed, tailored to each test condition. The questionnaire items (see appendix) covered the main issues addressed in the FEA as well as the official Operational Requirements Document (ref. 3). Each item was a phrase relating to a required or desired feature or performance characteristic. A quantitative rating scale followed each phrase. Various scales were used and wording changes were introduced from test to test but results show the questionnaires provided highly consistent results across tests. Changes in scale and wording appear to have had little, if any impact on results. That is, the same LBE design problems were identified in each test. Quantitative analysis of the scaled questionnaire was complimented by the qualitative written comments by the soldiers at the end of each questionnaire and statements made during the focus group.

These developmental tests involved experienced volunteers performing a number of load-carrying activities such as a road march, individual movement actions and/or simulated squad patrols or ambushes. During these activities the volunteers were required to don and doff loads repeatedly. Most activities took several hours and were followed by the questionnaire and team interview session. These tests were conducted at various locations and under varied conditions. One test, for example, was conducted in tropical heat with soldiers stationed in Panama and another in the Natick arctic cold chamber with experienced cold weather soldiers from Alaska.

During some of the early tests, MOLLE was tested along side other candidate modular systems while in the later tests MOLLE was either tested alone or with ALICE. In all tests volunteers were asked to rate MOLLE against their current LBE, viz., the ALICE. Upon completing the individual questionnaire, the team was brought together for a focus-group discussion. In most tests, the field actions and focus group discussions were video recorded for later review and analysis. The FEA and the developmental tests are briefly described below along with brief summaries of results, followed by discussion of lessons learned.

Results

Front End Analysis 1995

The FEA survey resulted in 1,280 fully completed questionnaires by soldiers and marines from eight military specialties. Fifty-six percent of the respondents were Combat Infantrymen, 14% Combat Engineers, 8% Medics and the remainder were Communications, Chemical, Mechanic, and other support specialists.

The respondents were given 32 statements about their current load bearing system and asked to indicate whether they agreed or disagreed, slightly or strongly, with the statement. The respondents were also asked to suggest improvements they would recommend for a future load-carrying system.

In addition to the survey, two "muddy boot" panels (n = 5 & 7) were conducted at Fort Benning, Georgia in September 1994, where each panel discussed, independently, the same set of questions as presented in the questionnaire. The two panels were then brought together to review their judgements and to arrive at a consensus about the requirements of a new load-carrying system.

The key findings of the FEA include a call for slightly more rucksack capacity and a capability to configure loads for different soldiers and missions. While it was recognized that greater capacity would mean a greater potential to over-load the soldier, the need to hold specialized items and the ability to quickly arrange and extract needed items from the pack were judged more important. Since heavy loads are nearly impossible to avoid during most real world missions, durability of the system and the added support provided by an external frame were identified as important requirements. The high rating on the ability-to-reconfigure requirement and the need to tailor loads strongly suggested the system should be modular. The emphasis on modularity was supported by the earlier effort of the Lightening the Soldier's Load Technology Demonstration of 1988. That demo concluded that making equipment modular allows fighting units to reduce loads through mission tailoring in theater. The dilemma, however, was that most removable components tend to lack the stability of fixed, sewn-on components. Thus, if the modularity concept was to work, an attachment mechanism, for providing better stability of components, was needed.

Focus was also given to the need for quick release of the main pack. While quick removal of the main rucksack has been a long-time desired feature, extra emphasis was given to this during the FEA. The FEA called for the development of a quick release mechanism. Discussions on the ease of donning and doffing of the rucksack lead to concerns about multiple belts and harnesses and the desire to simplify the system. This was reinforced by the expressed desire to make the load-carrying system more compatible with other worn equipment by eliminating competing belts and straps. For increased comfort, users asked for more padding, particularly on the shoulder straps. However, it was recognized that soldiers tended not to use their hip belts for tactical reasons (so they can quick drop the main pack when fired upon). Hence, there was a need for a more functional hip belt to help distribute the load but also allowed the pack to be dropped quickly. Thus, the FEA recommended the concept of a padded hip belt and other features for distributing or adjusting the load during prolonged road marches plus a quick release feature.

The FEA also presented a list of other issues, features, and performance requirements, such as camouflage, noise attenuation, water resistance, shouldering of the weapon, ability to clean, compatibility with other equipment, and so on. The FEA draft Requirements Document included nearly all of these with varying emphases. From this, TRADOC developed the official users' ORD for a new modular load-carrying system (ref. 3).

MOLLE 1997

The MOLLE started out as a load-carrying system for the US Marine Corps and incorporated many, if not all, of the required and desired features called for in the Army's FEA and ORD. Chief among these were modular pouches, a durable external frame with a reliable and durable quick release, a padded hip belt, and the elimination of the second belt of the load-bearing harness. The main pack and added pouches of the MOLLE had a capacity slightly greater than ALICE 's large rucksack and included special sized pouches to accommodate items for different users and missions. In addition, the system included the popular patrol pack from the previous system, a butt pack and fighting vest that allowed attachment of ammunition and other pouches. The real key to making the MOLLE a viable alternative was the innovative design of the attachment mechanism for modular pouches that gives each pouch a sewn-on quality, yet allows easy removal or re-attached to new locations on the load-carrying system. The other promising feature was the highly durable and reliable quick release mechanism for rapid dropping of the main pack. Prior to MOLLE no system worked well enough to be seriously considered to replace the ALICE.

Fort Campbell, Kentucky 1997

The first field evaluation of the MOLLE and another candidate was conducted at Fort Campbell in October 1997. Twelve US Army Rangers ran through an obstacle course wearing the full MOLLE or just the fighting vest. Actions included climbing under, over and through obstacles, low crawling, stepping or vaulting over barriers, balanced walking and a 5 kilometer march with a 23 kg weighted load. Between obstacles the soldiers had to doff and re-don the main rucksack several times. Following these activities the volunteers completed the Natick HF questionnaire and participated in the group discussions to compare MOLLE with ALICE and the competing system. The MOLLE was rated higher than the competitive system and only slightly higher than the ALICE. MOLLE scored highest on Modularity, Quick-Release, Ability to Vent, Quality of Closures, Holding Capacity, Feel While Walking, Stability of Pouches, Comfort with Loads and Durability. It scored low on Ability to Don Quickly, Quietness and Ability to Fire Weapon Prone. Based on these results the MOLLE was modified to make it easier to don by changing the probe design and shortening the frame.

Fort Benning, Georgia 1997

The second evaluation of MOLLE was again conducted with a group of US Army Rangers (n=13) at Fort Benning in December 1997. Prior to conducting mock patrols and ambushes in the field, the soldiers were given instruction and fitted on the MOLLE and practiced donning and doffing the ruck many times. They then spent much of the day in the field conducting various tactical movements. At night they went through night maneuvers to evaluate using the system in the dark. Following these activities they completed the Natick HF questionnaire and participated in focus-group discussions. The results again show the soldiers preferred MOLLE over the competitive system and only slightly over ALICE. They rated the modularity and pouch design very high. The loaded ruck was judged as highly stable and the frame durable. They liked the ability to shift the load while moving. Again, their greatest concern was the frame locking mechanism, time to don the rucksack, top-heaviness of a full load and the noise made by frame. There also were safety concerns (e.g., fingers getting caught in the locking mechanism). The MOLLE was again modified to address some of these issues.

Fort Kobbe, Panama 1998

The MOLLE was then evaluated by a U.S. Army test agency at Fort Kobbe, Panama in June of 1998. Here 49 soldiers used the MOLLE over several weeks, after which they were given a series of questionnaires including Natick's human factors questionnaire. The scale of the questionnaire was changed from a 0 to 5 scale to a 3+ to -3 scale to accommodate the tester in Panama. Wording was changed to match the new scale. The data show much the same results with highest ratings for the design of pouches, stability of pouches, clean-ability, repair-ability, capacity, reconfigure-ability, range of motion and feel while walking. The lowest ratings were for the frame-locking mechanism, re-donning times, problems low crawling, and balance with heavy loads. Nearly all the negative ratings related to the quick-release attachment system.

Natick Soldier Center 1998

Based on anecdotal reports from US Marines, MOLLE was judged not to be operable with standard issue army gloves. Therefore, a series of timed tests were conducted at Natick comparing the MOLLE and ALICE with volunteers (n=6) wearing gloves (July 1998). The results show the volunteers could operate the MOLLE as well as they could the ALICE. In fact, for many activities, volunteers performed better with MOLLE than ALICE due to improvements in snaps and fasteners. The only aspect of MOLLE that was worse than ALICE was the soldiers' donning of the rucksack. However, this was true both with and without gloves. Once again, the frame quick-release attachment was found to be a problem for the user in spite of a number of improvements. While some soldiers could re-don the pack reliably, there were many others who were unable to do so with any consistency[*].

[*] Although there is insufficient evidence at this point, observations suggested that anthropometric features of individual soldiers might play a role in the ease or difficulty of donning the MOLLE. It may be that individuals with certain back

Natick Cold Chamber 1998

In September 1998 Natick conducted a week long test of the MOLLE with the new Interceptor body armor in the arctic cold chamber using volunteer soldiers from Fort Richardson, Alaska. The volunteers brought their own cold weather gear and ALICE systems for comparison. Following several days donning and doffing loads, conducting tactical movements and marching in the cold (-23.3 C, wind-speed 4.1 kph) with 23 kg loads the soldiers completed the Natick HF questionnaire modified for cold weather operations, and participated in a team review. The results parallel previous tests. These soldiers rated Tailor-ability and Stability very high. They also liked the capacity it had to hold bulky cold weather gear. As in previous tests, these soldiers found the re-donning of the MOLLE pack quite difficult and gave a low rating to the detachable frame concept.

Fort Polk, Louisiana 1999

A variation of the MOLLE fighting vest (the "Rack") with shorter frame and "attached" or fixed belt was tested at Fort Polk with US Army Rangers during a field exercise in April 1999. The attached frame meant there was no quick release with the frame attached much like the ALICE. Forty-nine out of seventy soldiers completed the Natick HF questionnaires which also included questions on amount of time worn and usefulness of specific features. To accommodate various equipment items, special modular features were added to the MOLLE including a Leg Bag, PRC 126 Radio Pouch, Saber Radio Pouch, Map Cover, Claymore Mine Flap, Canteen Pouch, Snivel Pouch (butt pack), SINCGARS Radio Flap, and a Drinking Pack. The results mirror many of the earlier tests, with MOLLE receiving high scores on Ability to Reconfigure, Design of Pockets and Pouches, Durability, Closures, Stability of Pouches, and Comfort while Walking. Low scores were obtained on Ability to Fire Weapon in Prone Position, and Put-on and Take-off Quickly. In spite of the shortened frame, there were still complaints of the frame being too long. More accommodations were needed for soldiers with shorter body dimensions. While MOLLE continued to be rated low for ability to fire weapon in prone position, many soldiers admitted they would not expect to fire prone with a fully loaded rucksack. Furthermore, no one knew of a backpack that would allow soldiers to aim and fire their rifles prone. Thus, it appears this requirement was not to be met from the start.

Natick Soldier Center 1999

The last and most recent test of MOLLE using the Natick HF questionnaire was conducted in October 1999 and involved the evaluation of alternative frame attachments. These were, 1) the standard MOLLE single-probe quick-release; 2) a modified single- probe quick-release; 3) a double probe quick-release and 4) a fixed belt-to-frame system. Six US Army Rangers went through simulated squad movements in a forest area near Natick as well as an obstacle course and a 2-mile march. The volunteers carried 23kg and practiced donning and doffing the load repeatedly. In addition to being timed on the various designs, they completed the HF questionnaire and rated each system. For this test the scale was changed from a range of +3 to -3 to a wider range of +5 to -5. This allowed the user a greater range of responses and provided greater sensitivity during analysis.

The results show that the fixed belt version was rated extremely high relative to all other quick release versions. In this test, the volunteers first evaluated all the quick release candidates before they were given the fixed belt version of MOLLE. The ratings for the two-point quick release frame were higher than the one point for Balance and Stability. The two single point versions were rated higher on Comfort. Then, after the soldiers used the fixed belt version, the MOLLE was rated significantly higher on almost everything. The results show the soldiers overwhelmingly preferred the fixed belt above any of the quick releases. Every volunteer was ready to trade his ALICE for this version of MOLLE on the spot.

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and arm dimensions, as well as certain curvatures of the back have more difficulty donning MOLLE. To fully answer this would require a sizeable army-wide anthropometric study.

Discussion

In the early phases of the program to develop a new load-carrying system for the US Army, a comprehensive front-end analysis (FEA) was conducted which surveyed key users and identified a critical set of issues and requirements. From the FEA a detailed users' operational requirements document (ORD) was developed and from both the FEA and ORD the MOLLE emerged. These efforts reveal several things about the measurement methodology used, as well as, issues and features important to soldiers. The discussion below begins with some lessons learned about the measurement methodology used and is followed by discussion on which features of LBEs were found to work for the dismounted combatant and which did not.

Questionnaires and Focus Groups

Throughout this program short, simple, yet, comprehensive questionnaires were used in combination with relevant field and laboratory activities. Experienced users (soldiers) worked with engineers to arrive at designs that met their requirements. Although, from test to test, the questionnaires varied in minor ways in terms of wording and scales, the results were comparable across tests. In spite of the changes, the questionnaires identified the same strong and weak points of the load-carrying system that ultimately allowed engineers to tweak the design toward needed improvements. This was possible because of the combined use of fixed questions, written comments and focus group discussions. The combined data gave the design team confidence about the results. Furthermore, quantitative scaling of items allowed statistical analysis in support of decision making.

The lesson learned was that more important than scaling was the content and conditions of the tests and that testers need not always debate the merits of different scales or wordings since the variations proved the overall method robust. It was important to have a questionnaire that covered all the issues, users who had experience, and activities that represented the operational environment. It was also valuable to have at least one comparison item to which the volunteer could compare to the product being tested. While not every test reported above included the ALICE, the user-volunteers had sufficient and recent experience so as to allow them to subjectively compare MOLLE to ALICE.

Good Features, Bad Features

In terms of the findings about the load-carrying system itself, the most interesting part of MOLLE's evolution was how certain weaknesses were identified early, were repeatedly found in subsequent tests but were never eliminated. In spite of continuous product improvements, there was one feature the users were having fundamental problems with (viz., the quick release mechanism) and the design team and program managers continued trying to make it work. The quick release mechanism was, at that time, one of the great early innovations that appeared to solve a long existing problem. Desire for a quick release existed years before this program began. However, until the first MOLLE prototype appeared on the scene, no one had been able to design a mechanism that was reliable and durable. In addition, the belt-release mechanism allowed the elimination of a second belt, which was also identified by users as a key problem with the ALICE. The early excitement of the new design gave most of the team members and management a positive sense of accomplishment and a belief that it would ultimately work, once the bugs were worked out. It was hard for all those involved to let go of the challenge to solve what appeared to be minor problems. In the end, the voice of the user, in the form of accumulated data, became loud and clear.

The other great innovation, the pouch attachment mechanism, proved highly successful from the start. This too was documented early on in the data and, perhaps, contributed to the optimism about being able to make the release mechanism more reliable. It was the persistence of results that allowed better judgement to prevail. The only way the process might have been shortened, in this case, would have been if an attached belt alternative had been introduced sooner. But that, alas, is hindsight speaking.

References

1. Sampson, JB, Leitch, DP, Kirk, J, and Raisanen, GS, Front-end Analysis of Load Bearing Equipment for the U.S. Army and U.S. Marine Corps, TR-95/024, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA, June 1995.

2. Sampson, JB, Technology Demonstration for Lightening the Soldier's Load, TR-88/027, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA, February 1988

3. Department of the Army Operational Requirements Document (ORD) for the Modular Load System (MLS), Headquarters United States Army Training and Doctrine Command, Ft. Monroe, VA, 4 March 1996.

Appendix

HUMAN FACTOR EQUIPMENT QUESTIONNAIRE (Condensed)
Load System
User: ________________________________ Date: __________________

Rate equipment/system on each factor listed below:
Circle each item SEPARATELY. DO NOT OMIT ANY ITEMS.
(? = N/A or Can't Say)

	Very "Bad"			Neither |			Very "Good"	
1. Fit of Load-Bearing Vest (LBV)	-3	-2	-1	0	+1	+2	+3	?
2. Fit of RUCK & FRAME?	-3	-2	-1	0	+1	+2	+3	?
3. How COMFORTABLE was system?	-3	-2	-1	0	+1	+2	+3	?
4. BALANCE when loaded?	-3	-2	-1	0	+1	+2	+3	?
5. How STABLE while moving?	-3	-2	-1	0	+1	+2	+3	?
6. How easy to ADJUST?	-3	-2	-1	0	+1	+2	+3	?
7. Ability to PUT-ON QUICKLY	-3	-2	-1	0	+1	+2	+3	?
8. Ability to TAKE-OFF QUICKLY	-3	-2	-1	0	+1	+2	+3	?
9. How EASY-TO-USE w. gloves?	-3	-2	-1	0	+1	+2	+3	?
10. Ability BEND BODY wearing	-3	-2	-1	0	+1	+2	+3	?
11. Ability to BEND/MOVE ARMS	-3	-2	-1	0	+1	+2	+3	?
12. Ability to REACH pockets	-3	-2	-1	0	+1	+2	+3	?
13. Ability to WALK wearing	-3	-2	-1	0	+1	+2	+3	?
14. Ability to RUN wearing	-3	-2	-1	0	+1	+2	+3	?
15. Feel on SHOULDERS	-3	-2	-1	0	+1	+2	+3	?
16. Feel on BACK	-3	-2	-1	0	+1	+2	+3	?
17. Feel on HIPS	-3	-2	-1	0	+1	+2	+3	?
18. QUIETNESS of Load System	-3	-2	-1	0	+1	+2	+3	?
19. Design of CLOSURES/SNAPS	-3	-2	-1	0	+1	+2	+3	?
20. Design of POCKETS/POUCHES	-3	-2	-1	0	+1	+2	+3	?
21. Design of FRAME-LOCK	-3	-2	-1	0	+1	+2	+3	?
22. Design of BELT System	-3	-2	-1	0	+1	+2	+3	?
23. Compatibility w. BODY ARMOR	-3	-2	-1	0	+1	+2	+3	?
24. Ability to SHOULDER WEAPON	-3	-2	-1	0	+1	+2	+3	?
25. Ability FIRE WEAPON PRONE	-3	-2	-1	0	+1	+2	+3	?
26. Ability to LOW CRAWL wearing	-3	-2	-1	0	+1	+2	+3	?
27. Ability to CRAWL UNDER things	-3	-2	-1	0	+1	+2	+3	?
28. Ability to CLIMB OVER things	-3	-2	-1	0	+1	+2	+3	?
29. WEIGHT of System Empty	-3	-2	-1	0	+1	+2	+3	?
30. Ability RECONFIGURE missions	-3	-2	-1	0	+1	+2	+3	?
31. DURABLE/STRENGTH of system	-3	-2	-1	0	+1	+2	+3	?
32. Ability to HOLD MISSION ITEMS	-3	-2	-1	0	+1	+2	+3	?
33. STABILITY of Pouches	-3	-2	-1	0	+1	+2	+3	?
34. Ease of OPENING UP to vent	-3	-2	-1	0	+1	+2	+3	?
35. Design for GROUND ops	-3	-2	-1	0	+1	+2	+3	?
36. Design for AIRBORNE ops	-3	-2	-1	0	+1	+2	+3	?
37. Design for COLD weather	-3	-2	-1	0	+1	+2	+3	?
38. Design for HOT weather	-3	-2	-1	0	+1	+2	+3	?
39. Design for JUNGLES	-3	-2	-1	0	+1	+2	+3	?
40. Design for DESERTS	-3	-2	-1	0	+1	+2	+3	?
41. Design for CLEANING	-3	-2	-1	0	+1	+2	+3	?
42. Design for REPAIR	-3	-2	-1	0	+1	+2	+3	?
43. Design for STORING	-3	-2	-1	0	+1	+2	+3	?
44. Compared to OTHER LBE Systems	-3	-2	-1	0	+1	+2	+3	?

45. Comments: