PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL   [ ] REVISION NO. _____

Project No. __A-3067__   DATE __10/7/81__

Project Director: __Mr. N. L. Faust__   *ARMY*   School/Lab __EML/EOD__

Sponsor: __MERADCOM; Proc. & Prod. Director; Ft. Belvoir, VA '22060__

Type Agreement: __Delivery Order No. DAAK70-81-F-0491 under F33657-80-G-0077__

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Title: __Support of FEED__

ADMINISTRATIVE DATA   OCA Contact __Duane Hutchison x4820__

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__Ft. Belvoir, VA 22060__

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Defense Priority Rating: __DO-A7 under DMS Reg 1__   Security Classification: __None__

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See Attached __Government__ Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

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SPONSORED PROJECT TERMINATION SHEET

Date 10/7/82

Project Title: Support of FEED

Project No: A-3067

Project Director: Nick Faust

Sponsor: MERADCOM

Effective Termination Date: 5/31/82

Clearance of Accounting Charges: _____

Grant/Contract Closeout Actions Remaining:

[x] Final Invoice and~~Closing Documents~~

[ ] Final Fiscal Report

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Monthly Progress Report

Project A-3067
Contract No. DAAK-70-81-F-0491

for September 1981

Submitted by

Nickolas L. Faust

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

December 2, 1981

During the month of September, a dump of the FEED system software was acquired and loaded onto the EES S-250 system. Program listings were generated and organized into a two volume set (MAIN programs and SWAP programs) to aid in the familiarization with the system structure and for maintenance purposes. Questionnaires from previous FEED demonstrations were reviewed. The FEED van was left at EES for a week, and during that time a fan was installed above the CPU for cooling and a minor disc problem was corrected. An attempt was made to interface the digitizer tablet with the system, but the Tektronix board received was not designed for the box. Tektronix was contacted and they are pursuing the problem.

For October, EES personnel will travel to Ft. Sill, OK with FEED for HELBAT VIII in order to evaluate the system in the field, provide maintenance as needed, and assist in exercising the system. At EES, work will start on making components of the system operational on the S-250 computer.

Monthly Progress Report

Project A-3067
Contract No. DAAK-70-81-F-0491

for October 1981

Submitted by

Nickolas L. Faust

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

December 2, 1981

The FEED van was taken to Fort Sill at the beginning of the month, and was joined by one person from EES. While in the field, assistance was given with demonstrations and in preparing graphics used operationally in the exercises. The software was also modified to perform additional functions and some problems encountered in the field were debugged there. Others were worked on at EES after first converting the programs to FORTRAN V (for speed) and making them execute on the S-250 computer. The program that builds the polynomial data base from the DMA point data tapes was acquired and work was started on modifying it to execute on the S-250.

Plans for the month of November include: EES personnel returning to Ft. Sill for VIP week and to enter modifications made to the system; getting other system programs executing on the S-250; and processing DMA tapes.

Monthly Progress Report

Project A-3067
Contract No. DAAK-70-81-F-0491

for November 1981

Submitted by
Nickolas L. Faust

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

December 2, 1981

In the first part of November, Mike Rowan and Nick Faust spent time at HELBAT. There, software modifications made at EES were input into the FEED computer and other software errors subsequently found at HELBAT were corrected. EES personnel also attended VIP demonstrations in order to hear and elicit responses to the system to aid in the final evaluation report. Nick Faust also travelled to Washington, DC for three days to meet with personnel from ETL, DMA, and IITRI for the purpose of collecting information for the system evaluation. Additional FEED programs were bought up on the S-250 system with an interface so that the graphics can be plotted on the EES RAMTEK image processing system. A data tape was acquired from DMA and debugging and testing of the polynomial data base program started. Work was also started on preparing file layouts and reorganizing the directory and library file structure of the system.

In December, EES will begin writing the system evaluation report; software modifications and restructuring will continue, and possibly a trip to Ft. Leavenworth will be made.

(FINAL)   A-3067

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report is an evaluation of the Field Exploitation of Elevation Data (FEED) as it relates to the expressed objectives. Software and hardware were considered.

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1.0 INTRODUCTION

1.1 Purpose of Report

The purpose of this report is to provide an evaluation of the U.S. Army Engineer Topographic Laboratories (USAETL) Field Exploitation of Elevation Data (FEED) system based on experiences with it by the Georgia Tech Engineering Experiment Station (EES). Emphasis is placed on three major topics: the FEED demonstration tour and its objectives; technical aspects of the hardware/software system; and alternatives and recommendations for FEED. Information has been derived from a variety of sources including previously published FEED related research, army field manuals, questionnaires, interviews, and experiences of EES personnel with FEED.

The Engineer Topographic Laboratories (ETL) are tasked with the development of topographic and terrain analysis products to support the functions of the field army. Concurrently, ETL must evaluate and determine the form in which these products can be evolved to the battlefield. The 1980-1984 Department of the Army Consolidated Topographic Support Program (DACONTP) has an expressed interest in automated topographic support capabilities to rapidly produce terrain related cartographic products. It is within this environment that the FEED system has been developed.

1.2 Feed Background

The original impetus for the FEED system dates back to the early production of digital elevation data bases (DEDB) by the Defense Mapping Agency (DMA) and ETL sponsored research on data storage technologies and automated cartography. The research demonstrated that mathematical models could be defined that "reasonably" approximate the true surface form and provide for reduced data storage requirements. A detailed description of the techniques is found in reference 1.

In-house research at ETL also produced software for accomplishing terrain analyses (line of sight, terrain masking, etc.) on DEDB level one data provided by DMA. In 1978 the FEED program was initiated at ETL

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to "develop and test an experimental militarized computer interactive graphics system with the capability of exploiting digital topographic data based in a tactical environment."[2]

The program was managed by the Topographic Development Lab at ETL. The Electromagnetics Compatibility Analysis Center (ECAC) was requested to assemble and test such a ruggedized computer system and to modify existing ETL software so that it would operate on the new system. During the implementation period, ETL lost some of its in-house capability and more reliance was placed on ECAC personnel. The system was initially delivered to ETL in June 1980 for preliminary demonstrations at ETL's 60th anniversary observance. It was then returned to ECAC in July for further development. In December 1980 the system was delivered to ETL with a limited capability for demonstrations. In March 1981, the van traveled to Fort Monroe for its first series of demonstrations. ECAC personnel supported the FEED system by: 1) correcting existing software problems encountered in the field, 2) implementing new hardware (a militarized printer/plotter), 3) modifying the van to ETL requirements, and 4) by performing the software development needed to utilize the new equipment and to operate in a military grid coordinate system.

In April 1981, technical responsibility at ETL for the FEED project was transferred to the Geographic Sciences Laboratory (GSL). ECAC continued as the contractor support for the FEED system until October 1, 1981. At that time, ECAC withdrew their support of the project and Georgia Tech EES assumed the role of the FEED support contractor. From October 1, 1981 to the present, EES has been responsible for: 1) support of the FEED van in demonstrations and field operation participation, 2) software modification to correct errors or enhance capability, and 3) an evaluation of the FEED demonstration program and the FEED software.

1.3 Feed Components

The four general components of the FEED system are: 1) the source elevation date; 2) a polynomial terrain model; 3) hardware configuration; and 4) product producing software.

Source data for the FEED system is provided by the Defense Mapping Agency (DMA), which has been producing digital elevation data bases (DEDB) for approximately twenty years, to be used originally for special purpose mapping functions. It became readily apparent, however, that the utility of the data went well beyond the original purpose, both inside and outside the Department of Defense. A DEDB can be conceptualized as a grid covering an area, with elevations recorded for discrete geographic locations represented by grid intersections, and the data stored on a computer readable medium. The resolution, horizontal spacing between data points, is variable as regards DMA's collection efforts, but the standard product (Level I) is approximately 100 meters. High resolution (12.5 meters) data exist for a limited number of areas in the world. Overall locational accuracy for the Level I data is comparable to that of the 1:250000 map sheets.[3]

The second component of FEED is the polynomial terrain model, a technique which describes the structure of a topographic surface as a mathematical equation. An elevation value for any point on that surface can be derived, utilizing the equation and appropriate input parameters. An original impetus for the modeling techniques in FEED was to compress the amount of source data. Stated simply, at 100 meters resolution, the amount of data in a world-wide data base is tremendous. The polynomial terrain model in contrast, stores only a small portion of the data points along with coefficients for the equation that describes the surface.

These compressions are produced by representing N x N elevation data points, each normally stored in 2 bytes, as a surface equation whose coefficients can be contained in 6 bytes. The normal data volume for an N x N point set is 2N x 2N or $4N^2$ bytes. By using a polynomial, the same data are represented by 6 bytes. The compression ratio is then

$$R = 4N^2/6$$

If N = 10, then R = 66.6. A similar reduction can be achieved by subsetting the original data and using every 9th or 10th point in a row and every 9th or 10th row.

The current hardware configuration of the operational FEED system consists of:

1) ROLM 1602A processor (AN/UYK-19(U)),
2) CDC 80 megabyte disk drive and controller,
3) Miltope 800 bpi magnetic tape unit and controller,
4) Tektronix RE4012 graphics display terminal and attached Tektronix 4631 hard copy unit,
5) Versatec 7200 A electrostatic printer/plotter.

Miltope floppy disk units were originally installed but subsequently removed. A digitizing tablet was purchased but an incompatible interface board prohibited its installation. All of the equipment with the exception of the CDC 80 Mb disk is ruggedized and therefore potentially fieldable.

The final system component is the application software, producing five major types of graphics output: 1) line-of-sight; 2) terrain masking; 3) contour plots; 4) 3-dimensional (oblique) views of an area; and 5) perspective views. For each of the analysis modules the key component is an elevation profile. Contour plots are generated by connecting data from parallel profiles; terrain masking plots connect profiles radiating from a central point; and perspective and oblique plots use parallel profiles moving away from a viewer location. Examples of output and engineering theory for each of the above application programs are given in two reports.[4,5]

2.0 EVALUATION OF FEED DEMONSTRATIONS

2.1 Goals of Tour

The most appropriate way to evaluate the success or failure of any mission is to compare the results against the stated mission objectives. In documents relating to FEED, the following objectives were stated:

1) "...familiarize commanders and their staffs with the kinds of tactical computer graphics that can be produced in the field with existing technology."[6]

2) "...to determine the reliability of the hardware and software under adverse conditions."[7]

3) "...the accuracy of the digital elevation data and graphic outputs will be assessed."[8]

4) "...developing from potential users, statements of need and performance to guide ETL's continued exploratory development of computer assisted terrain analysis systems."[9]

2.2 Format of Demonstrations

The tour of CONUS bases began with a demonstration at Ft. Monroe on the 10-13 of March, 1981. Other bases were contacted by Cpt. Galley, and, if interested, a preliminary presentation was made on the types of products and services a FEED system could provide. Discussions were also held to determine where in the FEED schedule a demonstration could be held, and what arrangements were necessary to provide space and facilities for the FEED van. Normally after this meeting, a liaison person was selected and an announcement was sent to base personnel stating the FEED capabilities and its schedule while on the base. Interested personnel were then allowed to sign up for time slots for a presentation.

On the agreed upon date, the FEED van was located at the base, and normal setup procedures and liaison meetings occupied most of the first

day. One or more of the base personnel were trained on the FEED hardware to be able to assist in the demonstrations. This exercise normally took less than one day. Demonstrations for the following days occurred hourly between 0800 and 1700 with five to ten persons in each session.

During each session an overall presentation of the concept of FEED was made, including data types and potential uses of FEED type systems. Next, the hardware of the existing FEED system was detailed. During the hardware description, a plot was being generated on the Tektronix display CRT showing one of the types of analysis that may be performed using FEED. A discussion of all five analysis techniques used, including:

1) Line of sight
2) Terrain masking
3) Contour plotting
4) Perspective view, and
5) Oblique view,

followed showing previously calculated and plotted examples of each type of analysis on a bulletin board behind the FEED system hardware. The discussion concluded with explanations of the other types of terrain analysis that are currently being pursued at ETL.

If time remained for questions, they were fielded at this time. The viewers were asked to fill out the FEED questionnaire (Appendix 1) and to come back for more detailed answers if their time and the FEED schedules permitted.

In cases where the number of people signed up to visit the FEED van was small, the presentations were expanded and more time was available for user familiarization and the fielding of questions.

2.3 Satisfaction of Goals

Several hundred persons viewed FEED during the demonstration tour and approximately 10% completed the questionnaire. The overall results and cross-tabulations are shown in Tables 1-4. These results combined

Table 1

QUESTIONNAIRE DATA - TOTAL RESPONSES

Survey Question	Areas						How Employed					
	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other	Terr Apprec	Sensor Empl	Intelli-gence	Weapons Siting	Flight Ops	Other
Positive Responses	64	56	46	67	59	10	62	41	61	37	41	18
Total Responses	71	71	71	71	71	71	71	71	71	71	71	71
Percent Positive	90.1	78.9	64.8	94.4	83.1	14.1	87.3	57.7	85.9	52.1	57.7	25.4

Survey Question				Graphics						
	Line of Sight	Terrain Masking	Contour	Perspec-tive	Oblique	Military Features	Move-ment	Site Selec-tion	Other	
Positive Responses	62	64	57	50	57	49	43	54	11	
Total Responses	71	71	71	71	71	71	71	71	71	
Percent Positive	87.3	90.1	80.3	70.4	80.3	69.0	60.6	76.1	15.5	

Survey Question	Train-ing Sites	Battle-field	Location										
			EAC	Corps	Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty	Other
Positive Responses	46	44	21	38	37	27	16	47	27	19	15	17	24
Total Responses	61	61	60	60	60	60	60	60	60	60	60	60	60
Percent Positive	75.4	72.1	35.0	63.3	61.6	45.0	26.7	78.3	45.0	31.7	25.0	28.3	40.0

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Table 2

QUESTIONNAIRE RESPONSES - FIELD GRADE OFFICERS AND ABOVE

Survey Question	Areas						Terr Apprec	Sensor Empl	How Employed		
	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other			Intelli-gence	Weapons Siting	Flight
Positive Responses	26	22	19	24	22		22	17	21	17	18
Total Responses	26	26	26	26	26		26	26	26	26	26
Percent Positive	100	85.0	73.0	92.0	85.0		85.0	65.0	81.0	65.0	69.0

Survey Question	Line of Sight	Terrain Masking	Graphics				Move-ment	Site Selec-tion
			Contour	Perspec-tive	Oblique	Military Features		
Positive Responses	18	19	16	14	17	16	12	19
Total Responses	26	26	26	26	26	26	26	26
Percent Positive	69.0	73.0	61.0	54.0	65.0	61.0	46.0	73.0

Survey Question	Train-ing Sites	Battle-field	Location					TOC	Engr	Avia-tion	Signal	Arty
			EAC	Corps	Div	BDE	Other					
Positive Responses			6	12	10	9	4	13	11	2	4	4
Total Responses			26	26	26	26	26	26	26	26	26	26
Percent Positive			23.0	46.0	38.0	35.0	15.0	50.0	42.0	8.0	15.0	15.0

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Table 3

QUESTIONNAIRE RESPONSES - INTELLIGENCE

Survey Question	Areas						Terr Apprec	Sensor Empl	How Employed			
	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other			Intelli-gence	Weapons Siting	Flight Ops	Other
Positive Responses	27	25	16	28	17	3	37	17	24	17	11	3
Total Responses	30	30	30	30	30	30	30	30	30	30	30	30
Percent Positive	90	83	53	93	56	10	90	57	80	57	37	10

Survey Question	Graphics								
	Line of Sight	Terrain Masking	Contour	Perspec-tive	Oblique	Military Features	Move-ment	Site Selec-tion	Other
Positive Responses	28	28	27	26	12	23	18	21	3
Total Responses	30	30	30	30	30	30	30	30	30
Percent Positive	93	93	90	87	40	77	60	70	10

Survey Question	Location												
	Train-ing Sites	Battle-field	EAC	Corps	Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty	Other
Positive Responses	19	11	7	15	10	7	5	17	10	10	5	9	11
Total Responses	27	27	27	27	27	27	27	27	27	27	27	27	27
Percent Positive	70	41	26	56	37	26	19	63	37	37	19	33	41

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Table 4
QUESTIONNAIRE RESPONSES - ENGINEERING

Survey Question	Areas						How Employed					
	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other	Terr Apprec	Sensor Empl	Intelligence	Weapons Siting	Flight Ops	Other
Positive Responses	9	5	6	9	8	4	8	4	7	4	3	4
Total Responses	10	10	10	10	10	10	10	10	10	10	10	10
Percent Positive	90	50	60	90	80	40	80	40	70	40	30	40

Survey Question	Graphics								
	Line of Sight	Terrain Masking	Contour	Perspective	Oblique	Military Features	Movement	Site Selection	Other
Positive Responses	8	7	9	6	8	7	6	8	4
Total Responses	10	10	10	10	10	10	10	10	10
Percent Positive	80	70	90	60	80	70	60	80	40

Survey Question	Location												
	Training Sites	Battle-field	EAC	Corps	Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty	Other
Positive Responses	4	5	2	6	7	4	2	8	5	1	3	2	2
Total Responses	9	9	9	9	9	9	9	9	9	9	9	9	9
Percent Positive	44	56	22	67	78	44	22	89	56	11	33	22	22

with other materials and comments made during demonstrations are the basis for determining the extent that the FEED tour achieved its stated goals.

It is the opinion of EES that the FEED tour most successfully accomplished the goal of familiarizing commanders and their staff with the capabilities of automated terrain graphics. First, the demonstrations were presented in such a manner as to expose the viewer to a range of application areas. No single application was emphasized; rather diversity was stressed. The terrain masking algorithm displayed how one analysis concept could be applied to several tactical problems.

The fact that the viewers appreciated the potential applications is supported by the questionnaire responses. Ninety percent stated it would be useful in the accomplishment of their mission and equally important, it was viewed as useful across the areas of training, war gaming, mission planning, and mission execution. War gaming had the lowest favorable response at 65 percent, while the others were approximately 80 percent and above. Finally, all field grade officers and above stated it would be useful to their mission accomplishment.

The goal of determining the reliability of the hardware and software was answered during the FEED tour. Neither is reliable. It should be noted, however, that the hardware configuration was modified requiring corresponding software to be developed during the tour. It is unrealistic to expect error-free operation in such an environment. Nevertheless, other unrelated errors and problems exist.

The FEED application software appears not to have been fully tested prior to the tour, so that errors frequently surfaced. This condition was more prevalent during exercises such as HELBAT, where participants requested specific products, then it was in demonstrations where precalculated scenes were displayed. The reason lies in the fact that FEED provides the user with numerous options regarding scene content and viewing geometry so that the permutation of combinations for testing increases rapidly. A program can appear to function satisfactorily with one set of input data, but generate invalid results with another. Many

software errors have been corrected during the tour; however, others still remain.

The FEED system hardware encountered numerous difficulties on the tour, related to environmental conditions, and the rigors of cross-country travel. The FEED travel logs show system crashes as a common occurrence. Most reliability problems were related to the CDC disk drive. It is a nonruggedized component and not designed for operation in the FEED demonstration environment. Vendor maintenance was required on the device. Humidity caused problems at McDill AFB and during the HELBAT exercises at Ft. Sill. It should be noted that the humidity build-up at Ft. Sill occurred during several continuous days of very heavy rain. System startup was difficult but demonstrations were not impacted. Finally, the floating-point processor failed due to heat related problems at Fort Hood. The ROLM Corporation replaced the board.

In summary, FEED did not perform as a reliable fieldable system. However, only rarely did system errors directly affect a demonstration, and in such cases, presentations were made using previously generated hardcopy products. Viewers did not appear to have adverse negative reactions.

An evaluation of the goal of developing, from users, statements of need and performance does not provide a clear answer. If the goal is solely to generate formal requirements documents, then the demonstration tour was unsuccessful. On the other hand, if the FEED tour can be viewed as a step in a continuing education process in the utility of digital elevation data and automated terrain analysis, then indicators of partial success exist.

To be able to state system performance specifications requires an in-depth user understanding of system attributes and components. The cognitive and physical processes of extracting information from standard maps is familiar to users, but FEED, in contrast, has introduced a new set of variables. Data resolution and terrain modeling, for example, need to be understood and evaluated by potential users and combat developers.

Since normal demonstrations only lasted 30 to 45 minutes there was barely enough time to describe the FEED hardware and discuss sample plots of each type of analysis that could be generated using the FEED system. While there was occasionally time for questions and answers at the end of each session, there was no time for a potential user to receive hands on instruction as to the use of the system or to develop an analysis over a region of special interest. Even the military operator was taught only how to execute the programs and not how to set up an analysis. EES from its experience feels that a 30 to 45 minute demonstration of an analytic technique is not sufficient to allow a potential user to evaluate the effectivenss of that technique. Interaction with potential users is necessary in all phases of design and implementation of a successful analysis system.

The short time allocated to each site visit (3-4 days) was not sufficient to generate a consensus of usability by site personnel. In many cases the demonstrations occupied the FEED personnel full time for the period that the system was at the site. There was little or no time for interested personnel to come back informally to ask questions about the system.

In the original plan, after the FEED system had left the sites, a follow-up site visit was supposed to occur. This visit was to answer lingering questions on the FEED system, to gather comments as to the usefulness of the FEED system to the military units at the site, and to assist the site personnel in formalizing any requirements for digital elevation data that might have surfaced because of the demonstrations. Since the visits did not occur, no coordination of needs of the various units occurred, and any user suggestions as to how the demonstrations could be made more meaningful were lost. Instead of learning from each demonstration and modifying the approach taken in the system presentation, approximately the same demonstration was given at each site.

That no formal requirements have been generated does not imply a lack of interest in FEED. Many respondents noted on the questionnaires

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a willingness to work for the inclusion of digital elevation data and FEED-like capabilities in requirements. Some personnel specifically requested the assistance of ETL in the endeavor. Moreover, Fort Bragg formally requested the FEED software for extended testing and evaluation. The Human Engineering Laboratory wants FEED to return for its testbed exercises and other organizations such as FORSCOM want more technical information so as to be better able to evaluate its potential applications.

One major factor contributing to the lack of clear performance requirements for FEED is the absence of a specific role definition for the system. Indicators can be seen in the questionnaire responses. Answers to the desired accuracy question ranged from one meter to over one thousand. The latter was from a weatherman.

Essentially, FEED is a scale independent system; a positive design approach in the opinion of EES but related to the role dilemma. First, FEED can process evaluation data at any resolution, and second, it can output results at any user controlled scale. Finally, the user has some control over scene content. These conditions permit FEED to generate a broad overview scene of a large area or a detailed analysis from a hypothetical forward observer location. Correspondingly, accuracy requirements change with the role definition and scale.

The questionnaire gives only limited insight into the respondents' perceptions of role and accuracy. One reason is that the accuracy question was not associated with any specific role option. Nevertheless a few generalizations can be made. The median desired accuracy is 10 meters. Engineers generally have the more precise requirements with the median of 2 meters, whereas those with less stringent demands were in training and intelligence. Overall respondents see FEED as being less useful for site specific applications than for tasks which analyze more area. Generally, a large area analysis has relatively less precise accuracy requirements. Correct representation of the terrain form is more important than the elevation at any one point. It should be noted, however, that FEED was utilized for evaluating forward observer

locations and monitoring target locations, for example, at HELBAT VIII and its performance was viewed favorably. FEED's participation has been requested in future HELBAT exercises.

The goal of assessing the accuracy of the data and graphics output was achieved only partially in a subjective sense and not at all in a quantitative sense. No procedures were developed to measure and analyze errors. Graphics output was usually compared to maps, especially with overlays at scale. Small features frequently were in error, due to data resolution; however, in the experiences of EES, the overall surface trends were always correct.

It is probably unrealistic, considering all events happening on the FEED tour, to expect that data accuracy could also be assessed. Accuracy is a function of several variables, including: 1) the data resolution (horizontal spacing between sample points); 2) the order of the polynomial and the number of sample points used to create the polynomial; and 3) the texture of the actual surface. Both West Point[10] and ECAC[11] have published studies evaluating the accuracy of the polynomial terrain model, and the reader is referred to these studies for more detailed information. Accuracy is a valid aspect to evaluate, but it should not have been a goal of the FEED demonstration tour.

3.0 TECHNICAL EVALUATION

A technical evaluation of FEED involved problem identification in each of three functional areas: hardware, software, and data. Refer to Table 5, System Problem Summary, for a synopsis of the problems and suggested solutions discussed below.

3.1 Problems

Hardware

1. All of the FEED equipment is ruggedized with the exception of the CDC 80 Mb random access disk. Most reliability problems encountered in the FEED demonstrations were related to the CDC disk drive. While the CDC 80 megabyte drive is basically a good storage unit, it was not designed for rugged operation and could not be expected to withstand the jolting of cross country travel without problems occurring.

2. The Tektronix graphics display terminal serves dual functions which often impede each other. The use of the screen for both graphics output and operator interaction requires an awkward separation of actions. Graphics output cannot remain on the screen for analysis without becoming cluttered with operator prompts and inputs. Similarly, the use of the thumbwheel cursor for enhanced operator interaction is greatly diminished.

3. One of the limitations of FEED most noted by demonstration participants is the time necessary for the computer to produce the analysis once the input parameters have been specified. The execution speed of the central processing unit is the primary limitation that causes slow turnaround of user specified output products.

While no standard for acceptable time for product generation has been specified, a faster turnaround would foster better acceptance of the use of digital elevation data. Comparison with manual methods obviously favors FEED; the automated products are certainly produced many times faster than comparable products manually produced. Nevertheless, generating and plotting maps at the demonstrations occupied too much time to hold participants' attention. The attention

Table 5
SYSTEM PROBLEM SUMMARY

	PROBLEM	SUGGESTED SOLUTION	COMMENTS
HARDWARE	Non-Ruggedized Disk	Replace with Milspec Disk	Most hardware failures have been associated with disk - mobility seriously affected.
	Tektronix must serve dual function	Add low-cost CRT as terminal	User interaction interferes with graphics - degrades system use.
	Execution speed	Upgrade CPU	Specifications for time for analysis do not exist, but all users agree that processing was too slow - 1602A is ten-year old technology.
	Absence of digitizer	Integrate digitizer capabilities	Useful in relating digital elevation to standard map sheets.
SOFTWARE	Disorganized source files	Separate directories, create util. directory	A much higher degree of organization and documentation is needed if complex software is to be maintained
	Duplication in libraries	Restructure library scheme	
	Absence of documentation	Chart calling sequences & swaps, document all common areas	
	System back-up inadequate	Implement regular system back-ups	Needed for quick restoration of software in field
	Use of non-structured programming language	Use Fortran FLECS enhancement	Compatible with previous code - provides in-line documentation
	Operator interface crude	Implement menu-driven monitor & formatted screens & help function	Ease of use crucial for system acceptance

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Table 5 (Cont.)

	PROBLEM	SUGGESTED SOLUTION	COMMENTS
SOFTWARE (Continued)	Device dependent code for graphics devices	Isolate graphics calls for device independence	Provides capability to integrate new graphics devices or adapt to new environments
	Execution speed	Use optimizing compiler & I/O enhancements	
	Size	Implement extended memory	
DATA	No data capture capability	Investigate requirements for input data standards	DMA is data source
	Limitations of single variable	Add land cover data, slope, soils	Importance of slope, soils, vegetation characteristics identified by demo participants
	Accuracy of Level I data	Investigate trade-offs between data compression & spatial accuracy	100 meter resolution can skip important features
	Absence of data file documentation	Precisely specify all data file layouts & data flows	Effectiveness of software maintenance depends on this
	No procedures for handling multiple data sets	Establish procedures for naming, storing, moving, cataloging data sets	

span of demonstration guests does not necessarily relate to any production time standards. An evaluation is needed by specialists such as terrain analysts and intelligence personnel to specify the requirements for operational product generation.

FEED's processor is a ROLM 1602A sixteen bit minicomputer, which incorporates 10 year old hardware design and 15-20 year old technology. The technology now exists for a large jump in capability within the ruggedized family of computers.

4. The absence of a digitizer tablet limits the capabilities of the operator. The digitizer would be exceptionally useful in entering geographic locations and boundaries and in relating the digital elevation maps to standard map sheets. In areas where no digital terrain data exists, the tablet could provide a means of entering high resolution topography and feature overlay maps for analysis.

3.2 Software Problems

The FEED computer software is a very large and intricate set of programs developed to perform extensive topographic analyses. It is imperative that an improved level of software organization and documentation becomes standard.

1. Currently all source programs, including over 100 separate programs, subroutines, and functions, are maintained in one RDOS directory along with old versions of the programs and with the data files. Duplications and use of wrong program versions are inevitable, causing delays and introducing bugs.

2. The library file structure is currently established such that the same routine can be found in any of several different libraries. Again, duplication and confusions are the result.

3. The lack of attention to software documentation and organization severely impacts the ability to correct, update, and modify the system. The life span of such a complex system invariably spans the assignment of many different individual software professionals. A clear path through the maze of programs, algorithms, overlays, and data is

essential, if problem areas are to be pinpointed quickly, if enhancements are to be made without disrupting existing code, and if size and speed requirements have to be evaluated for change.

4. Procedures for regular system backup are not in effect and could result in delays and/or loss of recent software changes.

5. Use of a nonstructured programming language complicates programming logic and software maintenance.

6. The interface between the computer software and the operator must be further enhanced. The handiness and ease of use of the system for the operation must be considered very important just as the technical accuracy of the products is obviously emphasized. If the system lives up to its proponents' time-saving claims by facilitating analysis tasks, even encouraging further investigations otherwise too toilsome or time consuming, acceptance is insured. A primary goal must be to provide adequate richness of detail in analysis, while reducing the degree of complexity faced by the user.

7. Presently, much device dependent software is operating to control output to the Tektronix and Versatec devices. Software should be device independent to the greatest degree possible. Device independence means the degree to which the software is able to output to many different graphics devices whose operational characteristics are likely to vary considerably. Device independence provides for considerable flexibility in system configuration.

8. The need for improved system execution speed has been identified above under hardware considerations. Software improvements can also be made to affect execution speed.

9. Many of the FEED programs are quite large (relative to currently available memory) and fit in memory only because overlaying has been implemented. Introduction of all enhancements and modifications must take these size constraints into consideration. In addition, the operating system currently restricts the use of existing memory in the system. Even though the ROLM has a memory complement of

sixty four kilowords the operating system only allows one user to interface with the system and does not allow the extra thirty two kilowords of memory to be used as extended memory for program or array storage.

3.3 Data Problems

1. The source of data for FEED is DMA. A potential problem is the absence of data collection capabilities within the FEED system and the dependence on an external agency. It should not be inferred that any difficulties have occurred as a result of the arrangement, they have not. Ideal systems, however, should have data collection as one function, or at least have some administrative control over the process. FEED has neither. DMA produces data for many end users and does not set its standards for FEED. This condition could inhibit FEED developers from satisfying specific potential user applications that require different standards.

2. The ability to overlay other data sets for spatial association analysis is a powerful tool in geoprocessing systems, but it is here that the FEED system is at its weakest. FEED is essentially a single variable system and its analysis capability is limited to the information content of that variable. Many demonstration participants indicated that other sources of data such as land cover, vegetation height, and soils information would be extremely useful in evaluating mobility through the terrain. While it was felt that some justifiable analyses could be done with elevation data alone as a first approximation to the solution, most felt the need for more data in a fieldable computer system.

3. In some cases the accuracy of the elevation data used in the demonstrations was not sufficient to meet a particular user's needs. The data normally used in FEED demonstrations was Level I data provided by the Defense Mapping Agency (DMA). These data were coded from 1:250,000 scale topographic maps and are limited to the vertical accuracy of that map. For detailed sighting studies and other site

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specific analyses the vertical accuracy is not sufficient. Level II and Level III DMA elevation data would be required for these tasks. Unfortunately Level III data have only been collected over experimental test areas and are not generally available; it would require significantly more processing to produce a desired result; and due to limits in disk data storage, the detail provided by high resolution data involves the sacrifice of the spatial extent that a generated scene can cover.

4. Documentation of data files is not sufficient. Software maintenance and enhancements are complicated by the lack of data file documentation. Error recovery from problems with the several data, parameter, and swap files is not effective enough.

5. Procedures are not sufficient for handling multiple data sets. Improved data file management is needed.

3.4 Suggested Hardware Solutions

1. FEED's mobile configuration requires a milspec random access disk system be procured to replace the CDC drive. A ruggedized 35.6 megabyte winchester type disk is currently available from ROLM. A winchester disk is a hermetically sealed disk system which avoids problems with dust in the operations environment.

2. Introduce into the FEED system a standard, low-cost input/output cathode ray tube (CRT) to handle program editing and operator interface. The CRT would free up the Tektronix for graphics display simultaneous with operator interaction, as well as provide for input of coordinates using the thumbwheel cursor.

3. Specify the time requirements for an operational digital elevation product generation. Based on these specifications, upgrade the central processor from the ROLM 1602A to a ROLM 1666 or ROLM MSE/14 or MSE/25. Each of these systems would operate on 1602A FORTRAN code without modification and would provide significant advantages in performance.

4. Integrate a digitizer tablet and appropriate software into the system as a data input device.

3.5 Suggested Software Solutions

1. As a first step in improving the software organization, a scheme should be implemented placing the main programs in separate directories, linking them to a utility directory which contains exactly one copy of the routines they have in common, and linking them to a separate area where the data would be kept. Printed listings of the current software should be maintained in one central notebook.

2. The library file structure should be reorganized to eliminate the duplication among routines. When any routine is changed, it should be clear which library should be updated and which programs will be affected.

3. Complex software which utilizes many programs, extensive overlays, program swaps, and data work files must be accompanied by a clear chart of organization. Such a chart should be outlined to indicate all the program calling sequences, program swaps, and disk file names needed in operation. In short, this chart would be a picture of "who is doing what to whom." Additionally, all COMMON blocks should be documented to show what variables are included, what they are used for, and which routines share them. One possible effective scheme for standardizing COMMON blocks is to maintain all COMMON's in one disk file and use an INCLUDE like statement to locate the appropriate COMMON in each routine.

4. A regular procedure to back up the disk to tape should be implemented to protect all software and provide for quick restoration of the software in the field as necessary. A backup disk pack should also be standard in case of a physical error on the primary pack.

5. The programs can be far more effectively maintained if they are converted over to a structured language rather than using conventional FORTRAN. The FLECS structured software package, originally developed at Oregon State and available at Georgia Tech and elsewhere, offers many advantages over standard FORTRAN. For example, it 1) produces FORTRAN code which is fully compatible with most FORTRAN compilers currently

available, 2) is able to accept standard FORTRAN as input, so modifications to FEED software would not require massive, immediate changes, 3) can run on current FEED equipment and on any future proposed equipment, 4) provides structured programming that is easier to maintain and add to later on. A well written FLECS program can be virtually selfdocumenting. A FLECS user's manual is available as a Georgia Tech report.[12]

3.6 Suggested Data Solutions

1. Studies should continue to investigate the requirements for input data standards for FEED and FEED-like systems. Requirement specifications are essential for proper design and implementation of all enhancements. Specifications must be garnered from field experience as to the precision required for operational acceptance. These requirements could then be inserted into FEED data handling and software development procedures.

2. A significant modification would involve upgrading the FEED system to utilize multisource data. In addition to elevation data, the system would be able to support a geographic data base in which each layer of the data base consists of a spatial variable. Land cover and soils related data would each be a layer in the geographic data base. An overall geographic data base handling package would be implemented to allow combinations of multiple variables to perform analyses such as mobility across terrain.

The second modification would allow Landsat land cover data to be implemented as one layer in the data base. The current Landsat resolution is approximately the same as that for Level I DMA topographic data, and Landsat data are available worldwide. Many analyses could be done in any region of the world using only the generally available Level I data and Landsat data. The Landsat data would need to be preprocessed to generate land cover classes and their topographic offsets and geometrically rectified to map coordinates to overlay the DMA elevation data. It should be noted that Landsat D (to be launched in the summer

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of 1982) will provide spatial resolution four times as good as that of the existing Landsat data.

3. Specifying and recording all data file structures will enhance software maintenance and development. All data flows should be traced through the programs. This type of documentation will naturally be closely related to the documentation of the COMMON blocks suggested above in the section on Software. Pretesting for existence of the needed execution work files will provide graceful error recovery in their absence.

4. Improved data file management can be obtained by establishing procedures for naming, storing, moving, cataloging, and archiving all data sets.

4.0 FEED ALTERNATIVES

USAETL has several directions in which it may go in deciding the
fate of the FEED program. Some of the following alternatives may be
modified by combination with another alternative. The major options
available include:

1. Upgrade FEED software and hardware and use it to elicit user
    comments and recommendations from the Field Army to be used in
    the design of advanced digital terrain systems. Ways to
    achieve this goal are:
    a. Allow an upgraded FEED type system to participate in
        field operations.
    b. Implement a FEED-like system to be used by an operational
        topographic unit for training and user responses.
    c. Develop a non-milspec, low cost version for training.
2. Field FEED as it is, if requirements documents for it come
    forth from the demonstrations,
3. Dismantle FEED and continue doing research and development
    within AETL

If the option is chosen to upgrade FEED software and hardware so
that it may provide user input into the design of advanced digital
terrain systems, a number of factors need to be considered. Initially,
the FEED system should be withdrawn for a period of 3 to 6 months so
that the software structural modifications and detailed documentation
could be completed. A priority list for software implementation should
not occur until the documentation is complete. After the initial
restructuring of the software, the system should be tested by field army
personnel while new modules or capabilities are being developed on a
parallel configuration. The response from the field exposure should be
factored into the overall design concept.

If it is decided to allow the FEED system to participate in on-
going field operations such as HELBAT and REFORAGER, at least some of

the hardware upgrades should occur before initiation of the exercise. Since field operations are normally held in circumstances approaching a battlefield environment, a system to be used in such an exercise should be moveable and able to withstand rough treatment; therefore, at least the ruggedized winchester disk should be implemented into the system configuration. To make the FEED system more readily transportable it is suggested that the system hardware and retaining structure be designed to fit on a loading palette. If many requests are received for FEED participation in field operations, several FEED type configurations might be assembled. The overall purpose for the participation in field operations would be:

1. Pseudo-operational digital elevation data analysis in the field
2. Demonstration of spatial data base analyses as the computer programs for that analysis become available, and
3. Accumulation of user comments and suggestions to be used in design of advanced digital terrain systems.

One other way in which to consider user comments as to the usefulness and effectiveness of a FEED type system would be to allow regular use of a system by a unit in the field. If the system were used to plan and execute maneuvers jointly with combat arms units in the field, the resulting experience gained by Topographic Battalion personnel would be extremely valuable in the design of future systems. In addition, all involved units would come to understand the basic limitations of some computer driven systems and the advantages of others. Since many weapon systems are now being devloped that are driven by a computer topographic analysis such as TERCOM (for terrain matching along a flight path), and since the upgraded software for a FEED type system is inherently easy to use, FEED could provide insight for the soldier using such a sophisticated guidance scheme.

For training and evaluation of FEED type systems, the milspec version of FEED might not be necessary. A low cost (90K) minicomputer system could demonstrate all FEED objectives except field implementation. If several FEED type systems are desired for different

regions of the country or for different applications, the more inexpensive version might suffice.

If the FEED demonstrations result in a hard requirement for a digital analysis system that considers only elevation data, a system such as FEED might be able to satisfy that need with some modifications. As discussed in the above sections, the basic set of software and hardware are usable but not optimum in their present form. A fully milspec system, however, would be needed for fielding.

If option (3) is selected, FEED would be dismantled and work that is already in progress will continue toward developing an advanced digital terrain analysis system.

5.0 FEED RECOMMENDATIONS

EES feels that a FEED type system may be used to prepare the way for easier acceptance of future digital terrain systems. By using a precursor to such a system that will operate on currently available data with currently available hardware, Army personnel will acquire "hands on" training in the use of digital elevation data and will begin to learn of the power of spatial analysis using several variables.

1. Studies should immediately be performed to:
   a. define accuracy and timing necessary for a limited set of specific applications
   b. investigate the use of publicly available Landsat data to indirectly provide estimates of vegetation cover and heights
   c. investigate state of the art hardware that would reduce processing time for FEED functions.
2. Documentation of FEED software should proceed immediately. Documentation should include:
   a. programmers reference manual
   b. in-code documentation
3. A follow-up action should proceed immediately to gather information from FEED tour participants.
4. An upgrade of FEED capabilities should be initiated including:
   a. software upgrades for
      1. Implementation of overall Driver Structure for FEED
      2. Implementation of secondary data (such as land cover) to provide elevation offsets for FEED analyses.
      3. Implementation of a digitizing system for local data input.
      4. Implementation of a grid base multisource data analysis system.

b. hardware upgrades:
1. Replace CDC disk with militarized winchester type disk
2. Implement digitizer and alphanumerics terminal
3. Upgrade CPU to appropriate militarized higher speed system.

5. FEED should be allowed to participate in field operations that allow ETL to gather inforamtion as to the system's usefulness as well as allowing field units the ability to use FEED. For field operation participation:

a. an effective questionnaire must be developed to provide adequate information for FEED evaluation.

b. the agency/unit in charge of planning the field operation should define specific tasks that will be attempted using FEED.

c. a plan for accomplishment of these tasks should be detailed by the unit in charge and ETL personnel.

d. a plan for evaluation of results be defined to determine success or failure for specific tasks and to collect appropriate data.

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Appendix A

FIELD EXPLOITATION OF ELEVATION

DATA (FEED) QUESTIONNAIRE

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

FIELD EXPLOITATION OF ELEVATION DATA (FEED) QUESTIONNAIRE

1. Service: USA ✓____   USMC____   USAF____   OTHER____

2. Grade: G.O.____ Field Grade____ Company Grade____ NCO____ Enlisted ✓____

3. Branch/Specialty: (Engineer/Combat Development) _military Intell_____

4. Would terrain data be useful to your mission accomplishment? YES ✓____   NO____

5. In what areas?   YES   NO

    a. Training   ____   _✓_

    b. War Gaming   ____   _✓_

    c. Mission Planning   _✓_   ____

    d. Mission Execution   _✓_   ____

    e. Other:

6. How would it be employed?   YES   NO

    a. Terrain Appreciation/Orientation   _✓_   ____

    b. Sensor Emplacement   ____   _✓_

    c. Intelligence Preparation of the Battlefield _✓_ ____

    d. Weapons Siting   ____   _✓_

    e. Flight Operations   ____   _✓_

    f. Other:

7. For a computer-assisted graphics system like FEED to be useful (4-6 above), what
characteristics should it have?

    a. Graphics: YES   NO

                Line of Sight   _✓_   ____

                Terrain Masking   _✓_   ____

                Contour Plot   _✓_   ____

                Perspective View   _✓_   ____

                Oblique View   _✓_   ____

                Military Features   _✓_   ____

                Movement   _✓_   ____

                Site Selection   _✓_   ____

                Other:
                            33

b. Accuracy:

. Elevations (Z)   ± _/O_ m
   Locations of Features (X,Y) ± _/O_ m
   Other:

c. Performance:

   Produces graphics within _____ (time) ,
   _60_ minutes or _1_ hours

d. Location:

	YES	NO
Training Sites	✓	
Battlefield	✓	✓

Down to what level?

	YES	NO
EAC		
Corps	✓	
Division	✓	
Bde		✓
Other:		

Where specifically?

	YES	NO
TOC		
Engr		
Aviation	✓	
Signal		✓
Arty	✓	
Other		

8. Comments:

9. Date:

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IF you are interested in further helping to develop a need/requirements statement

for such a system, please complete below:

    Name: _____

    Rank: _____

    Title: _____

    Phone Number (A):   _____