DEPARTMENT OF THE ARMY
ARMY SCIENCE BOARD
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, D.C. 20310-0103

9 May 1990

MEMORANDUM FOR DEPUTY FOR SYSTEMS MANAGEMENT,
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
(RESEARCH, DEVELOPMENT AND ACQUISITION)

SUBJECT: Army Science Board Ad Hoc Subgroup on the Transverse Mounted Engine Propulsion System (TMEPS)

Attached is the Final Report of the Army Science Board Ad Hoc Panel on the Transverse Mounted Engine Propulsion System (TMEPS).

The Army Science Board, in coordination with your action officer, will publish this as an unclassified letter report in limited edition and controlled distribution.

THOMAS E. STALZER
LTC(P), GS
Executive Secretary

SQUARE D COMPANY
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May 2, 1990

Executive Secretary
Army Science Board
OASA(RDA), ATTN: SARD-ASB
Room 3E359, The Pentagon
Washington, D.C. 20310-0103

Attached is the Final Report of the ASB Ad Hoc Panel on the Transverse Mounted Engine Propulsion System (TMEPS), dated May 90.

The Panel Study was sponsored by the Deputy for Systems Management, Office of the Assistant Secretary of the Army (Research, Development and Acquisition). It focuses on the technical merit, achievable system efficiency and related costs of the TMEPS. It supports the recommendation to the Secretary of the Army not to provide additional funding for the TMEPS program.

Dr. Philip H. Francis
TMEPS Review Panel Chair
Army Science Board

PHF/mr

ARMY SCIENCE BOARD

REPORT OF THE AD HOC PANEL

ON THE

TRANSVERSE MOUNTED ENGINE PROPULSION SYSTEM (TMEPS)

MAY 1990

STUDY SPONSOR

MG JAMES C. CERCY
DEPUTY FOR SYSTEMS MANAGEMENT
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
(RESEARCH, DEVELOPMENT, AND ACQUISITION)

EXECUTIVE SUMMARY

At the request of the ASARDA the Army Science Board appointed an ad hoc Study Panel to review the basis for the recommendation to the Secretary of the Army that the Army not provide additional funding to General Dynamics Land Systems (GDLS) Division for the TMEPS program.

The Panel convened on April 26-27, 1990 at TACOM in Warren, MI, to review all background information made available, and also met with GDLS and Textron Lycoming officials.

The Panel found that the TMEPS program had been well executed, apparently meeting all program objectives except for vehicle testing currently scheduled for May, 1990. The advanced TMEPS concept could enhance the opportunity for FMS, and thus could continue to maintain an Abrams Tank production and readiness capability if significant FMS materialize. In addition, the advanced TMEPS program could contribute to fielding a 140mm gun capability ahead of current plans for a Block III system.

However, the design and implementation of an operational form of TMEPS, and other associated tank vehicle system modifications may produce difficulties in meeting all desired 140mm configuration objectives. Prospective FMS from this advanced TMEPS configuration are far from certain. Most important, however, is that there are alternative engine/power pack concepts now under study and development by the Army that could well lead to a system or systems that are superior to the GDLS TMEPS, and in about the same time frame.

After consideration of all these factors, the ASB Study Panel can not support a recommendation for the Army to continue the GDLS advanced TMEPS program.

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INTRODUCTION

The Terms of Reference required the Panel to "review the Army analysis and evaluation of the technical viability, achievable system efficiency, and related costs of the Transverse Mounted Engine Propulsion System (TMEPS) for the Abrams Tank," and then "from a scientific and engineering point of view, considering the above factors, determine the validity of the recommendation to the Secretary of the Army not to provide additional funding for the TMEPS." The Panel was further instructed "not to consider the relative validity or economics of other specific propulsion systems being considered for application in the Abrams Tank," but "... only to assess the validity of those conclusions in the Army study which concern the state of technologic development and economics of the TMEPS."

Strict compliance with these terms was difficult to achieve, as they appear to preclude establishing the context in which the recommendation was made, and thus the context in which the recommendation may or may not be valid. Furthermore, the "Army study" referred to in the Terms of Reference was not, insofar as the Panel could determine, formally structured, managed, or documented. The SARDA information paper, however, was made available to the Panel, as were various data developed by TACOM and General Dynamics Land Systems (GDLS).

INFORMATION REVIEWED

The following information was reviewed by the ASB Ad Hoc Panel:

- o Background information provided by the ASARDA.
- o Presentations and discussions by USA Tank Automotive Command (TACOM).
  - Abrams Tank system-overview of M1A2 program.
  - M1A2 system configuration elements description.

(Above included M1A2 system and program description, program drivers and requirements, funding and schedule, and potential for Foreign Military Sales (FMS)).

  - Armored Systems Modernization (ASM) program.

(Above included discussion of commonality/modularity,

acquisition strategy, and Block III tank program (Component Advanced Technology Test Bed (CATTB), Common Chassis Advanced Technology Transition Demonstrator (CCATTD)), and Block III Full Scale Development (FSD)).

- Cost Analysis of TMEPS and Advanced Integrated Propulsion System (AIPS).

o Presentation and discussion of TMEPS (current contract) and Advanced TMEPS concept/Abrams Power Train Evolution (APTE) system, and visual inspection of TMEPS Test Vehicle by General Dynamics Land Systems (GDLS).

REVIEW OF TMEPS TECHNICAL VIABILITY

TMEPS-Current GDLS Contract

TACOM information provided combined GDLS TMEPS development data and estimates of system parameters for a TMEPS operational implementation (i.e., the Advanced TMEPS or GDLS Abrams Power Train Evolution System). The Panel's assessment of the reported information follows:

Based on the data available to the Panel, the desirability of "repowering the Abrams Tank" is directly related to the desirability of upgrading the system to accommodate a 140mm gun and autoloader, and on-board storage of forty rounds. This upgrade would address a requirement to defeat a projected Soviet tank (which has not yet been fielded), for which the Army has put in place the development of a Block III tank, as part of its Armor System Modernization program. For the Army rationally to support the continued funding of advanced TMEPS, it must believe either that it may be confronted with a requirement for increased lethality before it can field the Block III, or that the upgunned (and thus repowered) Abrams tank is a substitute for the Block III, or that the upgunned Abrams tank would lead to FMS of sufficient quantity to preserve the tank industrial base prior to the initiation of the Block III. The panel was not provided (nor did it request) analyses which address these issues. The Panel assumes that these analyses exist and were considered in developing the recommendation to the Secretary of the Army.

GDLS appears to have met contract requirements, except for vehicle testing, which is currently scheduled for May 1990. The requirements demonstrated included: a) an integrated powerpack system which reduced the powerpack volume by 46 cu ft (insufficient for installation of 140 mm

gun with 20 hull-stored rounds and autoloader equipment); b) improved fuel efficiency (fuel efficiency improvement up to 15% was measured in engine dynamometer tests, although unresolved discrepancies exist between engine and powerpack tests); c) a new Self-Cleaning Air Filter (SCAF) was demonstrated with an equivalent of 200 hours operation in a zero visibility dust environment (this represents a possible order of magnitude improvement over conventional M1A1 filters); d) high commonality of parts (90% engine and up to 59% transmission). e) performance of a new Digital Engine Control Unit (which provided much of the overall fuel usage improvement).

The TMEPS is assessed to be a successful development and judged to be a technology basis for a workable transverse engine implementation. Its present configuration is of a development/demonstration nature and does not constitute an operational configuration. Although the basic TMEPS engine/transmission configuration is close to an operational one, definition and revision is necessary of many details of auxiliary equipment, plumbing, electrical equipment, power take-off, controls, and installation/tank modification details. Efficiency discrepancies must be resolved and the design of a number of elements experiencing failure during development testing must be reviewed. The SCAF and new cooling equipment requires optimization redesign and requirements for an Auxiliary Power Unit (APU) requires definition.

Advanced TMEPS Concept

The advanced TMEPS (or TMEPS FSD) concept is presented by both TACOM and GDLS only in gross conceptual form with no preliminary or detailed design or analysis. No approved performance or technical requirements exist. GDLS rationalized their conceptual proposal by referring to the desirability of timely upgrading of the Abrams tank, to increase its lethality by installation of the 140mm gun. Consequently, the TMEPS FSD is driven by the need to reconfigure the TMEPS to a suitably compact and efficient operational configuration. The principal requirement, therefore, is to increase the new available hull volume to 76 cu ft, which would permit the installation of 20 hull-stored 140mm rounds and the appropriate auto loader equipment, as well as allowing installation of required fuel storage. It should be noted that fitting a 140mm gun and about 20 rounds of stored ammunition could be accomplished without the introduction of a compact engine/powerpack and related hull/vehicle systems modifications by utilizing turret only modifications. Such a modification, however, would satisfy only about one half the apparent ammunition requirements.

It is the view of TACOM, and shared by the Panel, that the TMEPS FSD is feasible with moderate to low technical, cost, and schedule risk. However, because of the immaturity of the design and the lack of approved technical requirements, it is not clear to TACOM or the Panel that the postulated new available volume and the ammunition storage/ auto loader requirements can be met. For the same reason it is unclear that fuel storage requirements can be satisfied. Improved parts commonality is postulated by GDLS, but requires detailed confirmation. Finally, although the TMEPS development/demonstration established the feasibility of the hull and vehicle system modifications (requiring only depot level equipment, tooling, and facilities to perform cut and weld functions, and kit retrofit), these modifications and equipment/facility requirements require definition and qualification.

Discussion of Engine/Powerpack Alternatives

TACOM has provided estimates of overall TMEPS engine and power pack performance in comparison with other candidates (i.e., candidates for CCATTD). These other engines can be postulated to be configurable in a compact power pack implementation to yield the requisite new available Abrams hull volume.

Parameters for the AGT-1500 engine (the current Abrams and TMEPS engine) including power, weight and volume, and cooling load rate are competitive with other candidates. Fuel consumption, idle fuel flow (important because of total fuel requirements for operational duty cycles), and airflow (important because of its impact on engine compartment volume requirements and size of external porting) are significantly poorer.

The AGT-1500 engine is essentially mature, and only certain of the diesel candidates are comparably mature. The TMEPS engine modification, with the aforementioned efficiency improvements (principally due to turbine blade changes and the use of a new digital engine control unit), has only essentially the same testing hours as the AIPS engines. The other candidate engines are of similar maturity to the TMEPS engine which has evolved from the basic AGT-1500 engine.

Estimates of overall powerpack parameters were also made available by TACOM. These estimates indicated that the powerpack weight of a TMEPS (approximately 15,200 lbs) would be from 5-20% greater than the AIPS powerpack systems, and about 7% -14% lighter than the other candidate systems. Volume made available for the TMEPS FSD is, however, about 60% of that of the AIPS systems, but comparable to the other

candidates. TMEPS fuel consumption, based on a standard Battlefield Day duty cycle without an APU, is with one exception, about 140% greater than the other candidates.

Consequently, although the TMEPS FSD concept is technically feasible for Abrams installation, several other propulsion systems represent apparently feasible and attractive approaches, with several important advantages, even though not yet demonstrated in integrated vehicle implementation.

SCHEDULE, COSTS, AND ECONOMIC CONSIDERATIONS

The TMEPS FSD concept is described by GDLS as deliverable in the first fieldable unit (without consideration of a 140mm gun system) in 41 months from Authority To Proceed (ATP). This is viewed as somewhat optimistic by the Panel, although within the realm of possibility. A preliminary design study and an Automotive Test Rig (ATR) may be required which might add some 18-30 months. With very early ATP and nonconstraining availability of the 140mm gun system, it may be reasonable to deliver the first fieldable unit by 1997-98. In that the prototype engines are already available and the prototype powerpack for all other candidates could be available in the 1990-91 time period, similar overall fieldable unit conclusions could be made for all other candidate systems. It is important, nevertheless, to note again that the TMEPS is already integrated (in a prototype configuration) into the Abrams vehicle.

Overall systems costs, system Life Cycle Costs (LCC), utility, and COEA data do not appear to exist. However, TACOM presented estimates to the Panel for TMEPS based on recurring and nonrecurring costs, and LCC for the powerpack system. Further, TACOM provided comparative unit costs for the several candidate systems. These estimates are assessed as very preliminary in quality, and not sufficiently credible for FSD decisions. The TACOM analyst believes that, given the assumptions, these estimates have an uncertainty of 10% - 15%. Many of the assumptions, such as the use of an average unit cost over a production run much longer than likely, result in optimistic (lower cost) costs. The Panel, therefore, judges that the absolute values of the estimates, especially the LCC, may be significantly lower than the achievable reality. Excursions were not analyzed.

The manufacturing unit cost for the TMEPS powerpack (in FY90 constant dollars) is estimated at approximately $600,000. Development costs are estimated at approximately

$200 million. Total development and long lead items is estimated at about $500 million and total facilitization is about $300 million. By comparison, an AIPS estimate for development and long lead items is about $400 million, with non-recurring production estimated at about $470 million. AIPS unit costs are estimated at about $500,000. The approximately $100,000 difference in unit cost is very significant for quantities approaching the Abrams inventory (7,800 tanks).

A projection of Foreign Military Sales was also presented by TACOM. The projected total is 2,013 units, however, with considerations of the estimated probability of sales, the expected number is closer to 1,000 units. The Study Group judges that this projection is very speculative, with little credibility.

SUMMARY DISCUSSION

The Panel discussed the subject of the relationship between the repowering of the Abrams and Foreign Military Sales (FMS). It accepts and agrees with the view that FMS of the Abrams tank would be beneficial, particularly in terms of maintaining a production base. The Panel also recognized that provision of a potential upgrade to a 140mm gun system would make the Abrams more attractive to some foreign governments. However, it is difficult to quantify the magnitude of this effect; it is, at least on the surface, most important only to those armies which would face a Soviet threat, and it is sensitive to the timing of the introduction of the future Soviet tank. Without further analysis it is difficult to present any meaningful conclusions about the value of TMEPS to foreign military sales.

Putting aside the question of the desirability of upgunning the Abrams system, the Panel discussed the means of repowering the Abrams, assuming that a decision to do so was made. The Panel considered performance, cost and schedule data provided by TACOM and GDLS for the GDLS TMEPS program. It also considered the status of the TACOM AIPS program and briefly examined other engine/transmission systems. The AIPS program had among its goals the reduction of volume, and the reduction of O&S costs including fuel consumption, maintenance and support. The Panel notes that in terms of performance, cost and schedule, derivatives of the AIPS program could be developed and produced to repower the Abrams. Moreover, although data are incomplete and lack precision, it appears that such derivatives would be superior in performance (because of design goals and emphasis on O&S cost reduction) and at least equivalent in terms of cost and

schedule to the advanced TMEPS proposed by GDLS.

Figure 1 presents an overall summary of the potential opportunities and risks associated with continuing the GDLS TMEPS program.

FIGURE 1

OPPORTUNITIES & RISKS ASSOCIATED
WITH CONTINUING DEVELOPMENT OF THE
TRANSVERSE MOUNTED ENGINE PROPULSION SYSTEM (TMEPS)
FOR THE ABRAMS TANK

OPPORTUNITIES:

1. Would enhance the opportunity for Foreign Military Sales, thus maintaining an Abrams production and readiness capability.

o U.S. Abrams production currently scheduled to cease in April, 1993 - effectively closing down the industrial base.

2. Would possibly contribute to enable fielding of a 140mm capability ahead of Block III System.

o Estimated 2-4 year calendar advantage provided 140mm gun system is available. (Currently projected for type classification in FY97).

o Potential to upgrade 7,800 Abrams Tanks to 140mm capability (3,200 M1/IPM1 units @105mm and 4,600 M1A1/M1A2 units @120mm).

Risks:

1. May prove impractical to accommodate 140mm gun, autoloader and required rounds.

o Some uncertainty whether space will be sufficient for rounds, autoloader, and fuel.

o Requirements need to be specified (fuel, APU, etc), as well as detailed design to validate concept.

2. Foreign Military Sales may not materialize

o No firm orders or requirements for 140mm Abrams capability.

3. Alternative engine/power pack concepts, now under study and which might provide superior value, might be forfeited by pursuing the AGT-1500 TMEPS system.

o Such alternative engines/powerpacks could be available in prototype form in the 1990-91 timeframe.

CONCLUSIONS

1. The TMEPS development/demonstration is successful to date and established the basis for a technically feasible compact power pack for the Abrams Tank.

2. The decision to repower the Abrams must be made in the context (among other issues) of projections of the threat and evaluation of the anticipated progress of the Block III portion of ASM. The Panel was not provided such information, and thus can not comment on that specific decision.

3. Given the decision to repower the Abrams, feasible alternatives, having technical and cost advantages to the TMEPS approach, do exist.

4. Supporting decision analyses, such as utility analyses, COEA, economic analyses, impact on production facilities, alternative comparisons, requirements analyses, etc., do not exist or do not exist in sufficiently comprehensive or credible form.

5. TMEPS related analyses do exist, but are very preliminary, contain many suspect assumptions, are for particular selected cases, and vary in level of credibility.

6. Notwithstanding comments 4. and 5. above about the preliminary nature of present analyses, the observations in comments 1. and 2., which are principally based on technology development, and the conclusion in 3. still apply.

7. With respect to the Terms of Reference, the Panel concurs with the recommendation to terminate the GDLS TMEPS program to the extent that the data considered by the Panel does not permit the Panel to support the continued funding of the TMEPS.

CONFLICT OF INTEREST STATEMENT

Panel members had no apparent conflict of interest with any aspects of this particular study.

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, DC 20310-0103

24 APR 1990

Dr. Dennis R. Horn
Chair, Army Science Board
Associate Professor
Department of Civil Engineering
University of Idaho
Moscow, Idaho 83843

Dear Dr. Horn:

The Army is in the process of implementing a plan to modernize its armored forces. The tank modernization includes an upgrade of the Abrams system, designated Block II, and a new tank program designated Block III, which is part of the Armored Systems Modernization (ASM) program. The Block II program includes only modest changes to the M1A1 Abrams propulsion system. The Block III program technical objectives require a new propulsion system. The Army has invested heavily in new tank propulsion, as has industry. One such effort is a derivative of the M1A1 Abrams propulsion system designated Transverse Mounted Engine Propulsion System (TMEPS).

You are requested to appoint a panel of five to eight Army Science Board members to review the Army evaluation of the TMEPS for the Block II Abrams program, particularly as it relates to Foreign Military Sales, and prepare a report by May 8, 1990 addressing the validity of the Army evaluation. Your review of the Army evaluation will support further action by the Secretary of the Army.

The panel should address, as a minimum, the Terms of Reference (TOR) described below.

I. Background

The Army, during the period 1981 to 1990, invested over $100 million to develop two new propulsion systems for heavy combat vehicles. The program is called Advanced Integrated Propulsion System (AIPS), and is targeted toward a new vehicle, the ASM Block III Tank. As part of the ASM Block III effort, two propulsion systems will be selected for continued development as part of the Common Chassis Advanced Technology Transition Demonstrator (CCATTD). The CCATTD contracts are scheduled for award by June 1, 1990. The content of the

proposals cannot be discussed, however, there are seven engine and three transmission manufacturers that have actively marketed and are deemed viable competitors by Army technical experts. The two AIPS manufacturers are participants in this competition.

In addition to the Block III AIPS program, at the direction of the Congress, the Army contracted with General Dynamics for the Abrams Block II Tank to demonstrate a new propulsion system using the current Abrams engine, the Lycoming AGT1500, with changes to enhance fuel efficiency, in a space saving configuration. This is the TMEPS. This $14.2 million program will produce one demonstrator vehicle along with limited laboratory and vehicle testing. While retrofit of existing M1 Tanks is possible, the Army has determined that the costs outweigh the benefits, and costs will not be made up through savings.

Production of Abrams vehicles at both the Detroit Arsenal and the Lima Tank Plant is scheduled to end. Numerous options with potential to maintain a warm production base are being explored, foreign sales being one solution. The Block II Tank would have greater potential for foreign sales if designed to accept, in retrofit, the new tank gun and autoloader scheduled for Block III. This would require a propulsion system that occupies approximately forty percent less space than the current system. It has been suggested that the TMEPS program be augmented $20M for continued development for this purpose.

II. Terms of Reference

a. Review the Army analysis and evaluation of the technical viability, achievable system efficiency, and related costs of the Transverse Mounted Engine Propulsion System (TMEPS) for the Abrams Tank.

b. From a scientific and engineering point of view, considering the above factors, determine the validity of the recommendation to the Secretary of the Army not to provide additional funding for the TMEPS.

c. In making your determination, you should not consider the relative validity or economics of other specific propulsion systems being considered for application in the Abrams tank. Your task is only to assess the validity of those conclusions in the Army study which concern the state of technologic development and economics of the TMEPS.

The staff of the U.S. Army Tank Automotive Command and the Program Executive Officer, Armored Systems Modernization are available to assist in this effort. MG James C. Cercy will sponsor this study. The Cognizant Deputy will be Mr. George T. Singley III, and the Deputy Cognizant Deputy will be MG Richard D. Beltson. The HQDA Staff Assistant will be LTC Joseph L. Chabot, and the TACOM Staff Assistant will be Dr. Richard E. McClelland.

The panel should begin its work immediately. Arrangements have been made for the panel to meet at the U.S. Army Tank Automotive Command (TACOM) Warren, Michigan April 26-27, to be briefed on the Army evaluation of the TMEPS and conduct the review. The panel is scheduled to begin work at 0830 hours on April 26, at Propulsion Systems Division, TACOM, Bldg. 212. Dr. Richard E. McClelland's office (autovon 786-6411/ commercial 313-574-6411) will arrange for billeting, and assist with any other administrative requirements members of the panel may have.

Sincerely,

Stephen K. Conver
Assistant Secretary of the Army
(Research, Development and Acquisition)

Attachment

ARMY SCIENCE BOARD AD HOC PANEL

ON

THE TRANSVERSE MOUNTED ENGINE PROPULSION SYSTEM (TMEPS)

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