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ON MILITARY RDT&E IN ISRAEL

Alvin Jay Harman[1]

INTRODUCTION

In 1973--six months before the Yom Kippur War--I had the opportunity to exchange ideas about development practices in Israel and the United States with a number of Israeli participants and managers.[2] From these discussions, I realized that there are several reasons why a more thorough understanding of the military Research, Development, Test and Evaluation (RDT&E) process in Israel would be useful to a wider audience. First, through a combination of deliberate U.S. military assistance, receipt of sought-after technologies and skills, and development of internal capabilities, the Israeli experience provides a context for case study of successes (and of some failures) from which we can learn more about modes of military assistance. Second, and related to this, the Israeli process has made effective use of technology transfers and the product-improvement mode of development (e.g., in the enhancement of fighter aircraft and tank capabilities), while also revealing significant capability to develop their own entirely new equipment

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[1]The author is indebted to many individuals for providing information on and interpretation of Israeli practices, and especially to Alan Shapiro for thoroughly critiquing and adding to an early draft of this Paper. However, I am solely responsible for any remaining errors of fact, interpretation or omission.

[2]See my Analysis of Aircraft Development, The Rand Corporation, Santa Monica, California, P-4976, March 1973.

(such as short-range tactical missiles, the Uzi machine gun developed in the 1950s, or even the recently unveiled Merkava tank). Third, the effectiveness of both military assistance and internal capabilities seems to have benefited from a strong and continuing concern for real operational needs, reconfirmed from requirement validation through operational test and evaluation (OT&E). And, finally, either through incentives, organizational structures or other mechanisms, Israel has provided examples of rapid, efficient, and flexible response to evolving threats and technological opportunities that may provide insight into more effective performance in these regards in the United States.

This Paper does not attempt to fully analyze all aspects of Israeli RDT&E;[1] it has been deliberately limited to the pre-Yom Kippur War military RDT&E experience. I have attempted to abstract from individual instances of success or failure to provide an overview description of processes--especially focusing on the formulation of operational requirements, execution of development and operational testing, and the interactions of the technical and user communities.

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[1] On civilian R&D in Israel, see, e.g., E. Tal et al., Science and Technology in Israel, 1975/76, Jerusalem, National Council for Research and Development, March 1977 (translated June 1978); and M. Teubal et al., "Performance in Innovation in the Israeli Electronics Industry: Case Study of Biomedical Electronics Instrumentation," Research Policy, Vol. 5, No. 4, 1976, pp. 354-379.

The interpretation of incentives and motivations in R&D processes is always a hazardous task; analysis of such experience by a foreigner looking from outside the process compounds the dangers associated with making errors regarding "the facts" or their interpretation. While striving to avoid the main pitfalls, this Paper is offered as first cut at the "reality" of the RDT&E process of the early 1970s because: (1) Israeli practices should be particularly instructive since the effectiveness of the end products of these practices have been repeatedly tested in recent decades; (2) analysis of R&D processes in differing political and cultural contexts can reveal demonstrably practical policies that may merit adaptation elsewhere; and (3) such analyses of alternatives may encourage broader and useful public debate over appropriate processes for achieving essential national security needs.

HISTORICAL PERSPECTIVE

Prior to the June 1967 War, defense R&D had been managed on an ad hoc basis by a part-time chief scientist who acted as an adviser to the Minister of Defense and had no command authority. The three military services--ground, naval and air force--developed a great deal of autonomy and were essentially in control of their own assessments of requirements. Within the ground forces, and under the Chief of Operations within the military headquarters staff, a fairly small office existed for the development of "implements of fighting;" similar departments also existed within the IAF and the

Navy. Aside from intramural activities, much of defense R&D was performed in one institute, the Armament Development Authority ("RAPHAEL" is the acronym based on the Hebrew) that had existed for about ten years. Other principal developers were the Military Industries (TAAS) and the Aircraft Industries (TAA). These institutes were operated as independent establishments with fairly constant annual budgets. Under this system defense R&D expenditures had approximately doubled between about 1957 and 1967, but were still only about 1 percent of the GNP; the proportion of GNP devoted to total defense expenditures had increased by 50 percent during the same period.

Subsequent to the 1967 War, there developed a more formalized procedure for the initiation and approval of R&D projects. This trend culminated in about 1968 in the adoption of a system that closely emulated the U.S. system. The office of the Chief Scientist was greatly expanded (to about 50 people); it was moved to an intermediate position between the Ministry and the military staff and given some veto authority over R&D allocations--more over the exploration of new technologies than over the decision on new systems. Appeal from this authority could be made to the Chief of the General Staff or the Israeli Defense Forces or at the minister's level. Five categories of R&D activity were defined which roughly paralleled the steps from pre-R&D through 6.1-6.4 budget categories in the Department of Defense of the United States.[1] The initiative for promulgating "requirements" was left to the military, but the new Chief Scientist's office was given the opportunity to comment and make an opposing case if he so desired. Within the other categories (6.1-6.4), the Chief Scientist had considerable power. In 1970 about 40 percent of the R&D budget was under the direct control of his office. By 1972 the competition for the performance of defense R&D had expanded to three major establishments and about ten smaller ones.

In early 1971, the remaining two separate staff units for R&D--the Army's and the Chief Scientist's in the Ministry of Defense--were merged into one office. This is the office of Defense R&D (DRD), reporting both to the Ministry and to the Army General Staff.[2] The orientation of the office was also greatly influenced by the incumbency of technically oriented general officers to head it. The R&D is monitored by this office, but it also has its own budget and can operate in a mode much like the U.S. Defense Department's Advanced Research Projects Agency.

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[1]They identify five "levels" of R&D:

Level	Motivations
1. Pre-R&D/new concepts	Perceived deficiencies
2. Basic res/expl. development	Technological opportunities
3. Expl. dev/adv. development	Technological opportunities
4. Adv. dev/eng. development	Operational requirement
5. Eng. dev/system development	Operational requirement

[2]This consolidation was almost immediately modified by the appointment of a new Chief Scientist for the Ministry of Defense.

FORMULATION OF REQUIREMENT

In a service corps headquarters (for example, the general in command of armor) there will typically be a combined department of doctrines and operational requirements, with one office in charge. Out of this staff work comes operational requirements based upon the doctrine. The corps thus estimates the lacunae in forces and frames them in terms of operational needs--what is the situation (the operational problem) and what is the need? It also identifies the operational performance criteria to solve (or partially solve) the problem.

This statement goes to the General Staff, which decides if the request fits the broader overview of military requirements and whether it fits in with the other units under their command. Usually the operational requirements are not stated in too detailed terms but are defined in operational terms (for example, speed, agility, rates of fire) and not engineering terms (engine, horsepower, breech-load). Sometimes these requirements are written down on two or three pieces of paper. At the same time, the development institutions are also familiarized with the problem; they consider the buyer's broad options, and there is a constant process of communication and exchange of views and discussion of the limits on the state of the art. Needs and limitations of requirements thus become known to developers and operators in this phase. Sometimes they work without a written statement at first, but the paper statement is a necessary milestone at some point; without an approved

Operational Requirement, no development work (of their levels 4 or 5) is initiated. Suppose the Ordnance Corps is to be in charge of development; they may very well get other information, besides the very abbreviated Operational Requirement statement, through this preliminary phase of the process.

A necessary condition for the decision to proceed with development is an Operational Requirement, but they also consider whether it is worth the resources that will be absorbed. The office of DRD may conduct a systems analysis to assist decisionmakers on what to do. This is one input, but they rely also on "battle experience" and "educated intuition" of commanders--the decision is the commanders'.

When the General Staff approves the Operational Requirement, it goes to the Ministry of Defense where the principal scrutiny is budgetary. As mentioned above, the Chief of Defense R&D works both for the General Staff and for the Ministry of Defense, so that he can coordinate and implement the policy of the Ministry of Defense and the wishes of the General Staff.[1] If the Ministry of Defense concurs in the need to allocate resources to the operational need

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[1]In organizational terms, a review board is set up to handle each project (more on this below). At many points in these discussions, it will be clear that part of the effectiveness of R&D management arises because Israel is a small country. One of the most important advantages of being small was that, for example, the deputy of the Ministry of Defense was once the Deputy Chief of Staff of the Army, and personal acquaintance helps make the communication on decisions more direct. On the other hand, the increase in formal authorizations (since the time of ad hoc procedures prior to 1967) seems to have increased the lead time between the "idea" and the initiation of development.

that has been identified, it issues an order for development, which can be from two to ten pages, to the agency which will be in technical charge of the program. An attempt is made to specify this order in technical terms, but specific technical solutions are left to the engineers.[1] Also in this order for development is a specification of a rough time schedule. The budgetary frame is generally not detailed, but may be one number, such as a million Israeli pounds, or a flow of funding. This phase of the process is crucial to the ultimate development of useful systems.[2]

DEVELOPMENT ORGANIZATIONS, FUNDING, AND OVERSIGHT

With respect to the level of capability and the need to stimulate high quality work in the development laboratories or institutions, part of the General Staff (possibly the corps of engineers, or the signal, ordnance, and technical departments at headquarters, for example) is supposed to objectively assess the development centers. But there is a general pervasive faith in their development centers; e.g., "these are not private firms with solely profits motives," but

[1]There is a Hebrew saying, khabdaehu v'khashdaehu (in which "respect" and "suspect" are coupled), that captures the way in which the Defense establishment is said to deal with its development laboratories.

[2]For example, there is also a flow of ideas from the development laboratories and the defense industries at their initiative (as in the United States), partially in order to maintain their budgets with new projects as the old ones are completed.

are motivated most fundamentally by concern for survival.[1] Budgets for development institutions as a rule are allocated straight from the General Staff, in part from the office of the Chief of Defense R&D. There is a fairly complicated development budgeting process; although there has developed a more competitive environment among development establishments, it is still unclear to what extent development budgets vary through time in response to perceptions of how high a quality and usefulness the development efforts had been in the past.

On the question of how variable (fluid) are the employment levels of the various design groups, the typical description seems to be that "it's not like Lockheed." Most of R&D is done by government or quasi-government institutions and budgets are less flexible. For Military Industries and RAPHAEL, the budgets are not really very uncertain in the period up to the cease fire of August 1971, since forces were on active duty daily and received widespread political support. By contrast (from their viewpoint), the development budget available to Lockheed may be quite variable,[2] but for the U.S. Government military RDT&E budget as a whole is very stable. Moreover, in the United States, they observe, the relative strengths of motives

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[1] This pre-1967 article of faith about concern for the nation's survival may have become less pervasive in practice in the post '67 era. On the other hand, the concern for personal job security and the "survival" of individual defense R&D establishments increased in this period as a more competitive framework of development capabilities emerged.

[2] It is instructive that Lockheed was cited by some Israelis as an example of U.S. "private enterprise."

can be quite variable; incentives and motives (including non-pecuniary) may be quite different between Grumman and McDonnell. The incentives operating on the development institutions in Israel are taken to be more consistent across organizations; for the individual scientists and engineers, the pecuniary incentives have become increasingly important in the post-1967 period. However, there is also a highly prestigious annual Israeli Security Award granted by the Minister of Defense each year for an outstanding individual or group inventive activity. In a country with compulsory military service from 18 to 55 years of age, that award and the realization that the developer may become a user provide strong non-pecuniary incentives.

By the commencement of development--and often prior to the authenticated Operational Requirements (i.e., at the time of submission of a proposed project)--a special Board is appointed for each development program. There is a delegate on this Board from the General Staff, the office of DRD, the user branch (such as armor), a special group for material (for example, tanks or ordnance corps),[1] and a representative from the development institution itself. During development this special Board often meets once a month, but at least once every two months. The Board oversees the program from the beginning of development to procurement.[2] Information is said

[1]These are technical people--the branch that will be in charge of maintenance of the system.

[2]Other organizations within the Ministry of Defense, having fiscal responsibility for both development of new equipment and support of existing equipment, have the <u>incentive to take action</u> on what we in the United States refer to as life-cycle cost problems.

to flow freely between the developer and this special Board. The Board has the power to discuss technical problems; development problems having operational significance can be checked with the Board, but decisions to change the scope significantly go back to the General Staff.[1] The Board has the power to approve technical characteristics that will meet operational requirements. Their first job, in fact, is to endorse the technical solution for the operational requirement. They also are directly involved in the annual budgetary process.

OPERATIONAL TESTING

Operational testing is done to determine how equipment performs with the men in the operational forces, according to their best view of the appropriate military doctrine. Sometimes many separate test trials are performed; at other times technical and operational testing are combined to save the cost when the two can be easily distinguished.

Do "users" do the testing? It was repeatedly emphasized that at every step of the way, user participation is involved in the development process.

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[1] There is a requirement for a new cost analysis as a part of this type of change approval. Decisions on changes in smaller technical features are done by the lower levels of command; persons at the rank of Lieutenant Colonel have made such decisions. Documentation is modest and often simply records the decisions that are taken. Many problems are raised and resolved at a meeting called for the purpose of discussing the problem, with the appropriate people invited to attend.

In general there is a separation of development from test and evaluation as far as institutions are concerned. Developers conduct their own trials, but this is a formal "proof of nothing" from the standpoint of the military. Part of the development process involves formal provision of the hardware for tests conducted by the customer. There are two parts to these tests--technical and operational. The technical part is done by the corps or department responsible for maintenance. The operational part is conducted by that part of the headquarters in charge of doctrine and operational requirements--the originator of the perceived operational need. This is generally true. An example of an exception was identified with the ordnance corps in which the development agency itself was also the customer; thus it did the technical and operational trials.

The purpose of the trials is to see if the operational and technical characteristics have been met. There are two objectives basically. One is to judge if performance conforms to predetermined or pre-set requirements. For the second, they adopt the attitude "we don't care what we said before;" they want to know what the new piece of equipment can do and what its merits and shortcomings are. These two objectives usually hold even if not as a stated policy--especially the second (now that they have a system, they want it to be useful)--one of the desirable consequences of widely perceived limited resources.

On the question of when they make the decisions with respect to procurement and to the start of production, they postpone decisions very often to the latest possible moment and often after testing is completed. In many cases, the major technical features have been resolved and tested through prototypes. They make use of the developer's people, but processes, procedures, control and evaluation of operational testing is done by the Army itself.

There are a number of possible variations in the general approach to testing. In some cases the military does selective parts of the development trials. Sometimes they conduct in unison both technical and operational testing, under the control of the development board. There is almost no trial of which the development board and the General Staff is unaware (for example, even when testing is being done by the developer for his own information).

Among the distinctions between technical and operational testing, the technical tests focus on investigating the military characteristics of the equipment--for example, penetration, fragmentation, CEP. They also attempt to find out the reliability and maintainability of the new equipment, and they try to determine what should be the procedures for maintenance. They claim to rely heavily on American procedures (including formal Military Specifications) for testing; but they sometimes devise their own regulations and procedures also. Formally, there are two stages of tests: (1) prototype, to determine whether the functions are approximately what they anticipated (and to get some measurements in this regard), and (2) a final test of the hardware off of the final tooling.

Operational testing has no test equipment. They just look, for example, at the number of target hits in the operation, and they may use an operational squad (e.g., an armor unit) to carry out the test. The department in charge of doctrine and concepts has the authority to pull such a unit out of the forces for the testing. So "operational testing" places the emphasis on what the operational forces can do, partly because they can't afford to do it otherwise.

Major weapon systems follow the above scheme especially carefully. For example, an artillery rocket, launcher, and warhead are separate developments. The development institution tries each component in the field in the course of development. The Army sometimes suggests how to conduct these tests (even when the tests are for the developer's information). In these cases, the Army is not committed to results of the tests, even though they have made suggestions on how to go about it, and the developer does not have to accept the suggestions.

The procedures for formal testing are set by the Army. The headquarters of the branch of the Army interested in the new equipment receives technical test data, decides its testing plan,[1] and applies to the General Staff for their materials needed for tests. This is done under the coordination of the board. The length of the tests vary, of course; for example, two or three months for armored personnel carriers, cannons, or tanks.

The concepts for testing are among the last to be determined in the course of the development program. Plans for testing are devised near the time when testing is to commence. This is in contrast to

[1] Which may be in consultation with the development agency.

desires of the development agency, who would like to know as early as possible what kinds of tests are to be undertaken and to tailor the hardware to the tests, as well as to the operational requirements. In short, test plans are not prepared several years before the beginning of the test. Often test procedures would have to be revised if done that way, to get the insights into operational activities needed and relevant at the time of the test program. The rule of thumb is that when they can "fondle the hardware," and when they know the timing of delivery of the hardware to the month, then they plan the test. They deliberately plan to postpone such decisions on tests until that point, but to get acquainted with the more "theoretical" characteristics of the hardware up until then.

PROGRAM SCHEDULING, COSTS, AND PERFORMANCE

The development program schedule from the very beginning has a month and year identified when it is to be completed; but they don't hold to it irrevocably--often the outcome is within several months of the planned date or within a year (beyond that they "may get pretty angry"). They regard this schedule as a framework; a development agency is bound by something, so the military can press them.[1] The developers are also obligated to present the hardware for trial at a specific time. If the developer slips from the

[1] The Gabriel missile is a counterexample of a project with a spotty beginning (in terms of schedule reliability among other attributes) that eventually became an operational and financial success. It also provides an example of "technology transfer" between development agencies in Israel--increased competition between R&D establishments within the defense sector.

budget or schedule or performance originally sought, they demand an explanation. But, by contrast, the Israeli military finds the U.S. Congressional attitude of showing surprise at these slips rather silly, in that "it's a natural consequence of R&D."[1] The schedule is over target more frequently than it is under, but the incentives for efficiency and effectiveness are said to work fairly well--the groups who work on R&D want to finish their work as quickly as possible and get it to the Army. "An air-to-air missile used in combat successfully is the highest pride of scientists," so the incentives on the personal side are to compress the program.

On the cost side, when they start a big project they try to know what the total amount should be. They also want to know, at the beginning, unit cost of production. They sometimes use parametric methods, and they look at the quantities that will eventually be procured--in the hundreds, they'd expect a kind of "hand tooling," rather than "mass production" if the procurement is to be in the thousands. They need to get this rough idea so they can choose the right production technology. They don't decide the quantities for production at this point. They merely identify the neighborhoods of likely procurement. These calculations are done above the boards that supervise the development process, within the Economics Affairs Office of the Ministry of Defense.

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[1]The Israeli Knesset has displayed similar "surprise," however.

SEPARATION OF DEVELOPMENT AND PRODUCTION[1]

Design and development has not always been done by the same institutions that undertake the production. For example, the Military Industries originally were only production facilities of arms under license; by 1968 they had started to develop their own designs. Development and production seem to the Israelis to be more desirably done within the same facility, to pass the technology from design to production within the organization.[2] But there is a danger that the production concerns will dominate too early--if production people try to ensure that their producibility concerns are met very early. But the opposite concern is also present--that in design (by the technical specialists), due consideration might not be given to producibility if they are organizationally separate.[3] Producers would then have to redesign at the expense of time as well as money. Schedule slippage may make the whole program useless, in a rather

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[1] In this section, I deal with only one facet of this topic--the physical separation of the activities. Perhaps the more important "separation" is that between development and production phases for the purpose of evaluating the success and usefulness of the development product. This is a recognized and serious concern of the Israelis, and is discussed above in connection with testing activities.

[2] Their effective experience with licensing is an important counter example to this preference.

[3] The concern over these linkages reflects a universal problem (sometimes ignored in concurrency programs in the United States) but also some special organization history, as briefly alluded to above.

These kinds of concern over separation of development and production have led them to study the Rand report, System Acquisition Strategies (by R. L. Perry, G. K. Smith, A. J. Harman, S. Henrichsen; The Rand Corporation, Santa Monica, California, R-733-ARPA/PR, June 1971), and to translate it into Hebrew for wider distribution.

volatile Middle East context. In making some of these more subjective evaluations, the chief program officer in the development institution is expected to exercise good judgment.

THE ESSENCE OF BEING SMALL

Many of the features observed in Israel are claimed to be related to being rather small. They think they can define the problems quite well--"we see the dangers on our borders"--and this may be very helpful in getting the whole process started in the right direction. More than structure, however, there is said to be a philosophy of consciously taking advantage of being small. There are many examples of advantages of being small--including the fact that the people who are Chief of Armor, the Deputy, the major commanders, and the brigade commanders are all personally acquainted with each other; or that the general director of Military Industries went to the same high school as the Deputy for Plans in the office of the Chief of Defense R&D. Most fundamental, however, is the pervasive emphasis on flexibility and improvisation whenever practical.

THE ESSENCE OF BEING LATE

Israel need not break new ground technologically--it need only keep ahead of its potential adversaries. Thus it can economize by waiting for weapons to appear in the arsenals of the major powers before attempting to acquire the new capability by direct purchase, formal technology transfer (by means of plans or people), or initiating an independent development. The Shafrir air-to-air missile is an interesting case in point of the latter approach.

THE "QUICK REACTION" MODE

Israeli R&D may be most closely compared to what goes on in the United States during a "hot war," rather than to the overall structure for the development of "major weapon systems." U.S. practices include the occasional use of quick reaction funding.[1] There seems to have been an unfortunate trend in post-1967 in Israel to imitate the more formalized U.S. "major system" mode of R&D. Post-1973 Israeli attempts to remedy any perceived organizational deficiencies of such approaches may be instructive for the implementation of U.S. policy changes in the weapon acquisition process.

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[1] See, for example, P. deLeon, The Laser-Guided Bomb: Case History of a Development, The Rand Corporation, Santa Monica, California, R-1312-1-PR, June 1974.

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