

\$150 to \$200 million), what we have called exploratory development, and some genuine state-of-the-art advancement undertaken in connection with component and weapon system development.

Most weapon system and component development is undertaken by industrial firms on contract with one of the Services, although the Navy and Army still do some in their yards and arsenals. All three Services support extensive test facilities as well as administrative staffs to determine requirements, to let contracts, and to supervise performance under contracts. Research and exploratory development is divided between internal and external research centers and laboratories. A major share of the basic research is performed on contract by laboratories and individual scientists in universities.

PROBLEMS OF RESEARCH AND DEVELOPMENT

It is apparent that many of the problems of managing a research and development program have important economic aspects.

For example, the most fundamental problem of all, how much to spend on the program, is an allocation problem. Economic theory tells us that we "should" spend on research and development until the marginal gain from the expenditures, properly discounted, is just equal to the gain from expenditures elsewhere. But in the case of research and development, whether it is performed for a military Service or a business firm, this formula is peculiarly difficult to interpret or apply. The gain is much more uncertain — much harder to predict with accuracy — than the gain from, say, an additional fighter defense squadron with aircraft of known performance. This is particularly true of basic research and exploratory development, where the product, if any, will be knowledge — and knowledge usually far removed from any practical end use. Calculating gains from research and development is further complicated by the need for discounting. Typically the payoffs from research and development are expected in a more distant future than payoffs from procurement, since there is no enhancement of military capability until the results have been incorporated in operational hardware, procured, and deployed in operational units. This means that the discounted values of the payoff are highly sensitive to rates of discount — and as we have seen, there is great uncertainty about which discount rates are most appropriate.

These uncertainties make it difficult or, in many cases, impossible to use an explicit economic calculus to determine how much of total resources should be allocated to research and development; how these resources should be divided among the various kinds of research and development; and which specific projects should be selected. At the end of this chapter we will return to the question of what role economic calculations can play in answering such questions. Short of such calcula-