

though even there, as we shall see, it has limited usefulness and great dangers. In exploratory development and research the precise identification of objectives and scheduling are less important than trying to cover all good bets, selecting first-rate scientists and productive laboratories, promoting competition, and preserving flexibility to follow up vigorously on break-throughs.

SOME COMMON PITFALLS

TOO LITTLE "DUPLICATION"

One of the most important and obvious corollaries of the uncertain character of research and development is the desirability of some duplication. (Here, as is common in discussions of research and development, "duplication" means diversification or pursuit along several routes.) If, as is typically the case, there are two, three, or a dozen possible paths to some research and development objective, each with supporters and detractors, it will frequently pay to try two or more, not just one, which may fail or take an inordinately long time. In any rationally conducted program there should be duplication in this sense, and there will inevitably occur what appears with the aid of hindsight to be waste — the effort devoted to the unsuccessful (or less successful) paths.⁷

But how much diversification and where? No one knows enough to give precise answers. Some original and suggestive theoretical analysis indicates that in many circumstances there are great gains from pursuing two, three, or four paths, but rapidly diminishing returns from further duplication. Not only does the use of several routes buy time; it also, up to a point, actually saves money! The optimal amount of duplication in any particular situation is sensitive to the following factors:⁸

1. There should be more duplication, the greater the expected payoff from the research. In the Manhattan District Project, six completely distinct and independent methods of separating fissile material were under development concurrently; if the expected payoff had been less, fewer of these expensive "duplicating" projects could have been justified. Incidentally, the method that succeeded in producing the material for the first bomb was regarded at first as among the least promising. There is a strong case for some duplication in the development of critical weapon systems, despite their great cost, because of the disastrous consequences if the one horse that we back runs last.

⁷ For an excellent description of the uncertainties in R and D and the importance of "duplication," see Ely Devons, "The Aircraft Industry," in Duncan Burn (ed.), *The Structure of British Industry*, Vol. 2, Cambridge University Press, Cambridge, England, 1958, pp. 54-69.

⁸ For an ingenious attempt to quantify the role of these factors, see Richard R. Nelson, "The Economics of Parallel R and D Efforts: A Sequential-Decision Analysis," The RAND Corporation, RM-2482, November 12, 1959.