dominance—themselves partly inherent and partly chance—and impositions of the environment.

I liked this book. The empirical chapters are informative and well written. Clutton-Brock's thoughtful remarks articulate the common themes of *Reproductive Success*. However, lest I leave the impression that the study of selection in natural populations is inexorably bound on the road to fulfillment, I must recount several problems, to which the contributors themselves frequently allude. The calculation of I and its components and the relationship of I to fitness and to sexual selection have evoked considerable disagreement, in part because the indices do not formally constitute models relating life-table entries of age-specific reproductive output to fitness. This may be an issue of detail, but unsettling nonetheless. The practical problems of measuring LRS, which must include parental effects on recruitment and offspring LRS in many cases, and of accumulating sample sizes large enough to detect patterns amid the considerable stochastic and environmentally induced variation, seem overwhelming for all but the most amenable systems.

The degree to which LRS elucidates evolution depends on its heritability. The two studies in *Reproductive Success* that estimated heritabilities of components of LRS suggest disappointingly small values. Given time, evolution can and probably often does work with small selection differentials and low heritabilities, certainly below the limits of detection in field systems. Life-history theory tells us that negative covariances between fitness components generally constrain phenotypic evolution; the meager evidence for such correlations underscores the difficulty in detecting the general design rules for the architecture of life histories. Most variation appears to be irrelevant to evolution.

Lifetime reproductive success may provide the best measure of fitness, but is it a practical goal for field studies? Clutton-Brock and many of the contributors to *Reproductive Success* suggest that the answers to many questions will ultimately depend upon focused, experimental studies that effectively isolate one or several components of fitness. But because age-dependence figures prominently in most life tables and merits attention in itself, longitudinal studies will, as Clutton-Brock emphasizes, continue to offer unique insights.

Finally, Grafen provocatively asks, What are we interested in? He distinguishes two meanings of adaptation—the process and the result (of processes working in the past)—and suggests that while estimates of I can reveal present-day selection, they cannot explain present-day adaptations. The point is well taken, but the contrast requires further resolution. The end point of evolution depends upon the beginning point (phylogenetic effect) and its subsequent course. Evolutionary response depends upon selection and heritability (including genetic covariation). Thus, present-day selection/response and present-day adaptations (both themes of this book) may be uncoupled by phylogenetic history, environmental change, depletion of genetic variation, altering of genetic and phenotypic covariation, and weakening of selection by achievement of evolutionary optima. These sobering realities might discourage the weakhearted, but *Reproductive Success* has greatly helped to clarify goals and convince skeptics that field studies can elucidate the evolutionary process.

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Loci of Invention

The Sources of Innovation. ERIC VON HIPPEL. Oxford University Press, New York, 1988. xii, 218 pp. $27.

Technological innovations can yield economic benefit for their users, for the firms that manufacture and sell them as products, and for firms whose products they complement. The central argument of this book is that innovation, defined as the first reduction to useful practice of a new or improved technology, is most likely to occur at the locus where the profit (or more precisely, economic rent) captured by the innovator is largest. When product manufacturers in particular are unable to appropriate significant profits from innovation because of weak patent protection, easily copied know-how, or the absence of other barriers to imitation, users are apt to displace manufacturers as innovators.

This thesis is explored through case studies of original and improvement innovations in three classes of scientific instruments (gas chromatographs, nuclear magnetic resonance spectrometers, and electron microscopes), tractor shovels, engineering plastics and plastic additives, wire termination equipment, equipment utilizing industrial gases as an input, the manufacture of semiconductors and printed circuits, and the production of reinforced fiber (for example, epoxy-fiberglass) tubes and related shapes. A third of the book comprises illuminating histories of these innovations; the rest is more analytically structured. Subthemes include know-how trading, particularly among operators of steel mini-mills, and how would-be innovators can exploit the insights of "lead users" (for example, firms employing computer-aided methods to design printed circuits) to determine where a need for a new product exists.

The author's analysis is stimulating and for the most part persuasive, although he falls short when he attempts formal tests of hypotheses on how the locus of innovation varies with the extent of rent capture. He can estimate the magnitudes of rents attainable by product makers and users only subjectively, and given that many of his innovation categories were selected to illustrate one or another relatively pure case, there may be a problem of bias in sample selection. The author's methodology is particularly ill suited to support a proposition stated in the book's first paragraph: that, contrary to conventional wisdom, it is often not typical for innovations to be developed by product manufacturers. The two categories in which users rather than manufacturers played the predominant role, scientific instruments and semiconductor process technology, are almost surely atypical. The ability to jury-rig new apparatus is a requisite for professional success among the academic and industrial researchers who used the scientific instruments in von Hippel's sample. Thus, those users were unusually likely first implementors of new device ideas. Similarly, with respect to the semiconductor industry, my linking of 1976–77 U.S. patents to company lines of business showed that R&D in that industry is extraordinarily process-oriented, with 50% of its patents focused on internal process improvements, compared to 26% for all 15,112 patents in the sample (*Innovation and Growth*, 1984). Overall, roughly 95% of industrial R&D and patented invention does occur in manufacturing lines of business, and the vast majority is product-, not process-oriented.

My research nevertheless provides some quantitative support for von Hippel's thesis. Nearly 45% of the patents in my sample covered capital goods—that is, hardware used in production activities. The classification of patented inventions used in that study distinguished between those that had quite specific uses in three or fewer narrowly defined industries and those with widespread or ubiquitous industrial use. Among the specific-use capital goods inventions, fully three-fourths were developed within the industry that would use them. Thus, general-use equipment appears to come from *product* inventions by firms that sell the equipment whereas special-purpose manufacturing equipment is primarily the subject of *process* invention by the firms that will use

it. This dichotomy is readily explained in terms of the benefits-capture hypotheses articulated by von Hippel.

Even so, there is a puzzling gap in von Hippel's analysis. His references include two publications by Jacob Schmookler, but nowhere in the text are Schmookler's contributions discussed. Schmookler is best known for having emphasized the importance of demand as a stimulus to invention. But in his *Invention and Economic Growth* (1966), he synthesized "demand-pull" and "science-push" theories, arguing that demand may have its impact anywhere along the vertical chain from material and component suppliers through system assemblers to end users and that the locus of invention therefore depends upon where relevant science-based skills are best brought to bear. Von Hippel improves upon Schmookler's schema by showing that the ability to tap the profit potential of a demand pull may be stronger at one point in the vertical chain than at another. But he fails to recognize Schmookler's symmetric assertion that the skills needed to tap the relevant science base may also be more heavily concentrated at one point than at another. The innovation locus in scientific instruments seems as explicable by the preponderance of relevant scientific knowledge among instrument users as by the greater ability of users to capture the benefits generated by their improvements. Also, when skills are concentrated at one locus in the chain and the appropriability of benefits at another—a condition poorly illustrated by von Hippel's relatively pure cases—there is need for a more general, quantitative theory. One hopes that further work by von Hippel will fill the gap.

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The Beginnings of SDI

Lost in Space. The Domestic Politics of the Strategic Defense Initiative. GERALD M. STEINBERG, Ed. Lexington (Heath), Lexington, MA, 1988. x, 170 pp., $29.

The Reagan Strategic Defense Initiative (SDI) may have as many historians as it now has proponents and critics. The drama of its announcement in President Reagan's speech of 23 March 1983 and its shock effect on the bureaucracy and Congress guarantee that it will be a fruitful subject for study for many years to come. Certainly the topics covered in this study produced by the University of California's Institute on Global Conflict and Cooperation are crucial to any thoughtful political history and analysis of SDI. Unfortunately, the point at which this book was completed—1987—was too early to provide adequate perspective on most of the topics it covers. Nevertheless, the focus of the study is a useful one: the domestic politics of a highly controversial military research program.

The first two chapters, by Gerald Steinberg and G. Allen Greb, respectively, set forth what is common knowledge—that President Reagan's 23 March 1983 speech was not a carefully prepared and well-thought-out initiative. It was a rhetorical flourish, whose incubation was a carefully guarded secret. Nor, in all probability, was its enormous political impact foreseen by those who planned it. The boldness of the move and the surprise, excitement, and consternation it caused deserve a far richer contextual treatment than Steinberg's introductory chapter provides. Hedrick Smith, for example, in *The Power Game* gives a vivid and superb description of the "tiny power cocoon" in which the SDI concept was developed. And these events have been further dramatized in the Public Broadcasting Service series of January 1989 that grew out of that book.

The timing of the announcement and the unswerving commitment of President Reagan are keys to the enormous power of the "Star Wars" concept. Though antiballistic missile defense has had its advocates since the 1960s, the idea that nuclear weapons could be rendered "impotent and obsolete" was revolutionary and simply vaporized technical and bureaucratic obstacles that might have moderated or delayed the launch of the SDI program. The promise of eliminating the threat of nuclear weapons fed into the underlying fears that had generated grass-roots support for the Freeze movement. It also dealt with some of the moral issues that led to the May 1983 letter of the American Council of Catholic Bishops condemning mutually assured destruction as a policy.

It took several years of rigorous technical work and debate, as well as observation of what such a richly funded research program could actually accomplish, for technical skepticism to begin to have a wide audience. The American Physical Society report (which was published too late for this book) played a major role in legitimizing the technical doubts.

The SDI program has been altered substantially, even though $15 billion has been spent, and funding levels attained $4 billion in fiscal year 1989. This was less than requested but extremely high in comparison to other R&D programs, or even new weapons development programs. *Lost in Space* fails to develop the distinction between the political forces that supported the initial "space shield" concept and the continuing though eroding support for a far more modest set of defense concepts. SDI has gone through a major evolution from replacing deterrence to enhancing it, from full population defense to limited defense of silos and command and control or limited population defense against an accidental or aberrant launch.

Greb implies that the decline in the science advisory function may account for the lack of careful technical assessment of SDI early on. His historical description is interesting and accurate, as the collection of essays compiled by William Golden in *Science Advice* attests. But it is not at all clear that it would have made much difference in the case of the 23 March 1983 announcement whether or not President Reagan had a science advisory team on whom he relied for important technical judgments. In one sense he had a powerful science adviser, Edward Teller. An adviser in the Teller mold would have been likely to support President Reagan's enthusiasm, not dampen it. The critical political fact remains that the concept was kept from the knowledge of even many of the President's closest advisers on military matters, such as the Secretary of Defense.

In an era of widespread leaks and effective investigatory journalism, the ability of a small group in the Reagan White House to operate in absolute secrecy is a political phenomenon worth attention and analysis, particularly in view of the fact that a "tiny power cocoon" operated again in "Iran-Contra" with a somewhat different cast of characters.

The public fear and weariness of the balance of terror and willingness to accept a highly costly program that seemed to promise a shift in strategy away from mutual deterrence to defense are hardly explored in *Lost in Space*. Yet the contradiction and duality in public opinion have remained strong for many years, as polling data indicate. Americans harbor a serious fear of nuclear war. They support arms control, even while continuing to view the Soviets skeptically. But they also support a strong defense. SDI promised it all. The question that must be explored is whether this support will evaporate once population defense is deferred indefinitely and large resources are given for ballistic missile defense that may make strategic arms control non-negotiable.

The chapter by Pratt, Pike, and Lindley, "SDI contracting: Building a constituency," describes the very conscious strategy adopted by the Strategic Defense Initiative Organization of generating national support by