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The Society and Its Journal: The Emergence of Shared Discourse

We [John Rae, Carl Condit, Tom Hughes, and Mel Kranzberg] thought that an appropriate strategy would be to approach the History of Science Society and see if historians of science might widen their purview to include the history of technology. It so happened that Henry Guerlac, a leader in HSS, taught at Cornell. So a deputation went to see him. The meeting proved to be a disaster. . . .

We were crestfallen as we walked down the hill from Guerlac's home in Ithaca. "Well," I said, "if the History of Science Society is not going to 'condescend' to include the history of technology and if Isis is not going to publish any articles dealing with it, then maybe we ought to form a society of our own which would concentrate on the history of technology and start our own journal." The others agreed, but, they said, "It's your idea, Mel, so you do the work."—Melvin Kranzberg[1]

The year was 1957; the occasion the annual meeting of the American Society of Engineering Education at Cornell. Kranzberg, Rae, Condit, and Hughes, all members of the History of Science Society, met informally to consider ways to promote the history of technology as a new scholarly endeavor. Only after their unhappy encounter with Guerlac did the idea of an independent society take shape, and so, from a rib out of the side of the History of Science Society, SHOT (the Society for the History of Technology) was born.

Two challenges faced the leaders as they prepared, a year later, to publish the first issue of *Technology and Culture*. Would their society prove viable or would SHOT and the new journal linger for a time

on the intellectual scene before succumbing to the harsh demands of institutional survival? More central still, would the question that drew them together—the historical interpretation of technology—retain its vitality and mature into a living body of shared discourse? Would that discourse win new participants to the little group? Both issues remained in doubt in SHOT's first years.

Around 1963, however, both society and journal began to show evidence of emerging from their early frailty into a durable identity. The story of SHOT's success in meeting both challenges, structural and intellectual, is the subject of the first chapter. They will not, however, be given equal weight. The central purpose of this book is to search out and articulate the language that historians of technology have created to interpret the technological past. The organizational history of the society will be treated in summary form while the lion's share of the chapter will explore the intellectual foundations of the discourse we find in the articles of TC's first two decades.[2]

The Society's Constituencies

SHOT's early development depended on four key constituencies, distinct in function, although blurred in their boundaries by overlapping membership. Two—the subscribing readership and the financial supporters of the venture—while necessary for survival, were less significant than the core group of society leaders and the larger constituency of contributing authors. TC's subscribing members numbered 688 in the first full year of publication. They grew at a healthy annual rate of slightly more than ten percent through 1967, when the rate of growth stabilized at its present level of approximately five percent. The contributions of the second constituency, SHOT's financial contributors, were vital during its first decade. Individuals and foundations offered grants to support society functions and to make up TC's operating deficits, which persisted until 1972, the journal's first year of modest profitability.[3]

In its early years the society's leadership constituency numbered fewer than twenty regulars. Almost all wrote articles for TC. They served on key SHOT committees, planned annual meetings, reviewed books, evaluated articles, and developed relationships with other scholarly and technical societies.[4] The tasks performed by the group were less important, perhaps, than the dynamism emerging from their enthusiastic commitment to the new field. As we shall see, the founders did not readily agree about the scope of journal offerings or, more

important, about the definition of "the history of technology" itself. The vigor of their debates and the passion with which they pursued their sometimes conflicting goals provided an intellectual excitement that, more than any other factor, insured the survival and growth of the society.

From 1964 on a substantial number of younger scholars were attracted to the society. Successful recruitment of new leadership was a critical test of the society's long-term viability, and the process begun in the mid-sixties continues to the present. Typically, a potential leader begins contributing to the society by reading papers at annual meetings, by reviewing books for the journal, and eventually by publishing articles and serving on key committees. It is difficult to indicate exactly how many individuals should be considered leaders because no two people relate to the society in the same way. Nevertheless, the evidence suggests that this critical constituency more than tripled to approximately seventy-five members by 1980.[5]

Contrasting the early group who published articles before 1964 with those who have published in the last ten years reveals the changing nature of the author constituency. Evidence from journal correspondence indicates editor-in-chief Melvin Kranzberg had to work with a very small backlog of manuscripts until mid-1963.[6] Sixty authors wrote the sixty-eight articles published in the first four volumes. Nearly a third of the group, including most of the leaders of the society, identified themselves as historians of technology, of science, or of both.[7] Another fifth were historians from nontechnological areas. The remainder, nearly half the authors, represented a wide range of nonhistorical disciplines. Technical perspectives, such an engineering, science, economics, and business, tended to dominate, while the broad cultural perspective of the social sciences and humanities was less well represented.

The early bias toward engineering and science was even more pronounced than this evidence suggests. The idea of a society for technological history emerged at a meeting of the American Society for Engineering Education; many of the original members were active in the History of Science Society; and the society maintained active relationships with the History of Science Society, the American Association for the Advancement of Science, and numerous engineering societies.[8]

Several other characteristics of the early author group are noteworthy. Marjorie N. Boyer was the only woman to publish an article in the first four years, an indication that SHOT was an almost exclusively male organization at the outset. Scholars from outside the United States, particularly non-English-speaking authors, were a striking mi-

nority. Kranzberg recognized this lack and periodically made efforts to broaden the international scope of the author group, but with little success.[9] SHOT leaders wrote nearly one-third of the articles themselves, and several of the group, most notably Kranzberg, actively solicited contributions from other scholars. Kranzberg asked many well-known individuals for manuscripts and negotiated sets of articles published as single-theme issues in the fourth number of each volume.[10] Efforts like these led to an impressive array of articles—and representation on SHOT committees—by scholars who had become recognized in the second third of the century for pioneering studies of technology. They included Lynn White, Jr., William Fielding Ogburn, Cyril Stanley Smith, John B. Rae, Peter Drucker, Lewis Mumford, Howard Mumford Jones, Roger Burlingame, Abbott Payson Usher, S. Collum Gilfillan, A. Rupert Hall, A. Zvorikine, James Kip Finch, and Jacques Ellul. While most of this group were relatively inactive in SHOT affairs, White, Ogburn, Smith, and Drucker would serve as presidents of the society. In particular White, Smith, and Rae threw themselves into all aspects of the society's affairs.[11]

When we contrast this early group with a profile of the most recent ten years we see several significant shifts. The percentage of articles written by historians of technology or science rises from 32 percent to 48 percent. The overall percentage of historians increases from 59 percent to 72 percent. Indeed the influence of the historical approach on TC's authors is understated by this profile. As we shall see, the percentage of articles written in a nonhistorical format drops dramatically after the society's early years.

By the end of its second decade, the society and the journal had settled into a pattern of sustained membership growth and modest fiscal security, and they had moved more and more in the direction of a specifically historical community of scholarship. While there remained considerable openness to nonspecialist contributions, the growing percentage of articles written by members of the new profession suggests that the history of technology was beginning to dominate the journal's offerings. As it matured, TC more completely reflected the organization's name: the Society for the History of Technology.

This summary of organizational growth suggests that SHOT and TC have served as a forum for historical discourse about technology and that scholarly exchange within that forum has begun to generate a coherent intellectual focus for the field. Failure to find such a focus would have been fatal for SHOT. It would not serve to say, year after year, that the topic, the history of technology, was "interesting." Unless the members of the society began to interact so that the field took

on an intellectual life of its own, the conclusion would correctly be drawn that the topic was sterile precisely because it had generated little shared discourse of moment. The continuance and steady growth of the journal and its relevant constituencies comprise evidence that this process of intellectual self-definition has in fact been taking place.

This conclusion is substantiated by one of the major findings in an author survey—a combination of personal interviews and written questionnaires—conducted in 1977. Ninety-five of the 191 authors who had published in TC responded. By far the most common response to any question in the survey was that indicating that TC has created a forum in which scholars of diverse backgrounds, often working in isolation, can publish and interact. One reply is typical of many. "T&C has been very important in giving scholars a focus for their research. This has helped to form a community of scholars."[12]

The Formation of a Viable Intellectual Focus

From the first, SHOT's struggle for intellectual identity has been rooted in a debate about method. Given the diversity of approaches to technological scholarship extant at its inception, it is not surprising that the society's members found consensus difficult. The question, as seen in SHOT's correspondence and in TC articles, was how to combine the two competences—technical and historical—whose interrelationship was claimed by the title of the journal.[13] Those who insisted that technical competence, as found in the best internalist research, was a sine qua non for history of technology argued that an excessively broad definition of the field would invite the publication of "soft" articles whose lack of technical competence would tarnish the reputation of the journal.

The demand for technical sophistication was more than matched by arguments against a pure internalist style. Several historiographical articles in the first three volumes pointed out that exclusive emphasis on design neglected complex interactions between the design and its context. All too often, it was argued, technological history was limited to success stories implying an autonomous technological determinism. The new society could meet a critical need by providing historical analysis of the failures, contingencies, and multifaceted components of technology's societal ambience.[14]

The two positions did not necessarily exclude one another. Advocates on both sides tended to criticize the other as a pure position, and it is true that some articles published in the first four years embodied pure internalist or pure externalist positions. Nevertheless, the ar-

guments for the two approaches did not rule out an integration of the two after the manner of historians such as Lynn White, Jr., or Louis Hunter. In fact, although it was far from clear during these early discussions, the society's majority position, as seen in the body of published articles, would eventually favor the difficult integration of technical detail and its context.

The difficulty of this integration is illustrated by a striking parallel. In the first article of the inaugural issue of TC, Kranzberg explained the scarcity of extant literature studying "the development of technology and its relations with society and culture."

Serious historical scholars, with but few notable exceptions, shied away from the field because of a feeling that they lacked *the requisite technical knowledge* to treat it properly . . . [but] just as few historians are learned in technology few engineers are skilled in the *rigors of historical research.*[15] (my italics)

The contrast between "requisite technical knowledge" and "the rigors of historical research" is provocative because it is mirrored in technological praxis itself. It is clear that both the designing and the maintenance of technological artifacts demand detailed attention to functional design constraints. It is equally clear, however, that technological practitioners who design or maintain such artifacts are deeply influenced by the often ambivalent contextual factors that constitute the artifact's ambience. Technological activity does not occur outside this tension between design and ambience. Thus Kranzberg's tension between technical and historical expertise is directly parallel to the defining tension of technological praxis itself. In the words of Lewis Mumford:

History as the interpretation of the changes and transformations of a whole culture must necessarily take account of technology as one of the essential components of a culture, which in the very nature of the process affects, and is affected by, the pressures and the drags, the movements and resistances, the creativities and torpidities of every other aspect of society. By the same token, the historian of technology will find his account of technical processes seemingly isolated from the general flux of events, far more significant when he *restores technology itself to its dynamic social context.*[16] (my italics)

This discussion, helped as it is by two decades of development in the field, presents the tension between technical design and historical ambience in clearer terms than were available to SHOT members at the time. Their decision to name the journal *Technology and Culture*

can be seen in hindsight as a decision favoring the integration of internalist analysis with contextual method.

TC's historiographical articles show that the debate continued well beyond the early years. Only twice in the first twenty years do we find a substantial number of these articles. The first cluster dominated the early issues of 1959 through 1961. The second appeared in 1974. In that year's first issue a set of three articles by R. P. Multhauf, E. F. Ferguson, and E. T. Layton, Jr., addressed major historiographical questions.[17] In the following issue European historian Reinhard Rürup published a parallel study of the field from a European perspective. Taken together, these articles provide a glimpse of the status of the field's intellectual self-definition in the early seventies. The articles written by Multhauf, Ferguson, and Rürup are of particular interest here because each attempts to assess the present state of the art.[18]

The central themes in all three articles are remarkably close to the core issues of SHOT's earlier debate. Multhauf and Ferguson stress the lack of a "conceptual framework" for the field. They acknowledge the existence of a body of specialized internalist history but point to the lack of unifying concepts to integrate the several technologies within a single universe of discourse.[19] Multhauf calls attention to the small number of internalist scholars responsible for a great proportion of the French, British, and American multivolume histories of technology that had appeared in the past two decades. It would be, he notes, falsely optimistic to infer from the existence of the three works that internalist scholarship was in anything more than its early stages.[20]

Ferguson and Rürup, on the other hand, stress the importance of developing a set of thematic questions that link internal design with societal context. They identify key issues, such as the nature of innovation, the validity of the concept of autonomous technology, the relationships between technology and science, between technology and economic forces, and between technology and other cultural forces.[21] In his penultimate paragraph Rürup summarizes the challenge facing historians of technology in terms remarkably close to the "design-ambient" tension.

The social relevance of the history of technology lies—both for the present and for the future—in its critical function. We can use it to learn to distinguish between *technological necessities* and conscious and unconscious *social decisions*[22] (my italics)

In these three articles we find the two sides of the early debate—the need for technical competence and for historical integration of design

and context—to be as central to historiographical discussion in the early seventies as they were a decade earlier.[23]

Further evidence of SHOT's methodological tension between design competence and historical sophistication can be seen in the author survey of 1977. The most common perception of the authors who discuss the "caliber of TC's scholarship" is that journal articles are of mixed quality even though TC is clearly the best journal in its field in the world. Many authors note "the broad range of topics and research styles in the articles" but their evaluations do not fit a single pattern. One group indicates that breadth of coverage is one of TC's best qualities, while the other considers it a distinct liability. Those who criticize the presence of too much internalist research are only slightly more numerous than those with the opposite complaint.[24]

An array of opinions about "the intellectual character of the field" recapitulates the main lines of the debate. Author perceptions on this issue fall into three clusters. The largest group refers to the difficulty and necessity of integrating what are seen as two distinct styles— technical design and contextual history. One author describes the greatest weakness of the field as "the gap between internal technical history (e.g., the lathe) and social-impact-of-technology history." Many of these respondents also indicate that TC's broad variety of research styles is the most important factor in the evolution of such an integration. Two smaller and equal-sized groups argue that the history of technology demands one of the two competences without reference to the other.

This survey of TC's authors taken near the end of two decades of the society's existence confirms once again the central hypothesis advanced here. The Society for the History of Technology began in 1958 as a small group of scholars with an extraordinary range of professional backgrounds. They lacked and felt the need for a forum within which they could meet one another and so begin a process of disciplinary shared discourse. While some held polar positions that can be called "internalist" and "externalist," their mutual participation in the single arena provided by SHOT created an intellectual climate fostering the difficult integration of the intricacies of technical design with the complexities of the cultural ambience of such designs.[25]

Scholarly Ancestry

In the thirty years before the birth of SHOT, research that would play an important role in shaping TC's methodology had begun to develop along three separate lines. For our purposes they can be termed "in-

ternalist history of technology," "nonhistorical analyses of technology," and "contextual history of technology." The internalist tradition is directly descended from centuries of European scholarship, but the second and third lines of research are much more recent and appear to be the result of initiatives beginning in the United States. Before we analyze all three in the context of the United States, however, it will be helpful to trace the development of internalist research in Europe and to consider briefly several other continental forms of scholarship, which have had less impact on TC's methodological formation.

"Internalist history" receives its name and heritage from the centuries-long tradition of interest, and indeed fascination, with the design characteristics of human mechanisms. It is "internal" history because the focus of attention is centered almost completely on the artifact itself rather than on how the artifact relates to its external social context. Its ancestry can be traced as far back as Giovanni Tortelli's *De orthographia dictionum e graecis tractarum* of 1449. Tortelli's work stands at the beginning of a long line of histories and encyclopedias of inventions culminating in von Poppe's *Geschichte aller Erfindungen und Entdeckungen* of 1837. Von Poppe categorized technological subject areas in a way that proved influential until well into the twentieth century.[26] After a hiatus of nearly fifty years we find evidence of renewed interest in the history of technology in the work of German scholars such as Amand Freiherr von Schweiger-Lerchenfeld and Ludwig Darmstaedter. Their individual contributions presaged a modest flowering of German interest marked by the beginning of work on the now-famous Deutsches Museum in 1903, the formation of two journals, *Beiträge zur Geschichte der Technik und Industrie: Jahrbuch des Vereins Deutscher Ingenieure* (Berlin, 1909) and *Archiv für die Geschichte der Naturwissenshaften und der Technik* (Leipzig, 1909), and the internationally recognized work of Conrad Matschoss, Ludwig Beck, and Franz Maria Feldhaus.[27]

The founding of the Newcomen Society for the Study of the History of Engineering and Technology in 1920 provided an institutional matrix for research in Britain. British research, unlike the German movement, survived during the World War II with the continuous publication of the *Transactions of the Newcomen Society*. After the war continental scholarship experienced a renaissance in France, Germany, Sweden, and Italy. Scholars of the first rank such as Bertrand Gille, Maurice Daumas, Torsten Althin, and Friedrich Klemm were of particular importance. Soviet history of technology has until recently had little connection with the traditions just mentioned. The work of the Institute of the

History of Technology at Leningrad from 1929 to 1937 was strongly influenced by its commitment to Soviet national pride and a Marxist interpretation of the relationship between technology and socioeconomic change, which sharply distinguished it from other scholarship. In the United States, as I shall indicate, internalist historians participated in the larger European universe of discourse. Thus the internalist methodology that would form part of the immediate ancestry of TC's intellecutal style was common to both sides of the Atlantic.

By contrast, nonhistorical analyses of technology based on sociology, economics, and political science have taken distinct paths in Europe and the United States. Neo-Marxist scholars, such as Jürgen Habermas and Herbert Marcuse, have had greater impact in Europe than in the United States. They form part of a larger European trend toward studies of the relationship between technology and society in terms of inclusive and elaborately articulated models, the most famous being Jacques Ellul's analysis of the deterministic power of "la technique." American studies of technological impact, such as Lazarfeld's analysis of the influence of television on children, tend to be more narrowly focused on particular technologies or analyses of the economic ramifications of innovation.[28] Finally, there appear to be few European parallels to what is described below as "contextual history of technology" which antedate TC's first volume.

The following analysis of TC's three immediate methodological ancestors is aimed at revealing the inchoate state of the art in 1959 and at underscoring the tensions within the early society in its search for intellectual identity. Each analysis is limited to a few important works, which are presented as exemplars of the essential characteristics of the three styles.

Internalist history

Between 1954 and 1962 major multivolume histories of technology were published in Britain, France, and the Soviet Union. These works represented the dominant style of the field at the time of SHOT's formation.[29] Internalist history was practiced by small clusters of scholars and antiquarians specializing in the design characteristics of single types of technology. Although interaction within such groups was vigorous, the several clusters tended to function in isolation from one another. "Technology" as a general term calling for collegiality across particular technological lines was not an operative concept in most internalist history.[30]

The History of Technology, edited by Charles Singer, E. J. Holmyard, and A. R. Hall, exemplifies this style. It defined technology as "how

things are commonly done or made" and "what things are done and made."[31] The five volumes resemble an encyclopedia of technologies whose several historical developments are treated independently of one another. The "historical developments" of interest tend largely to be abstracted from the political and cultural fabric. Commentators on Singer's history and its parallels in France and the Soviet Union recognized that these volumes represented only a beginning of internalist work. The field was young, practicing scholars too few, and the works produced often suffered from a dearth of critical and collaborative research.[32]

Nonhistorical analysis

The work of Jacob Schmookler, William Fielding Ogburn, and S. Collum Gilfillan, although emerging from the two distinct fields of sociology and economics, represented a second style of research influential in SHOT's search for identity.[33] Each scholar, by choosing to make technology the centerpiece of his theoretical model, departed from the normal practice of his discipline. Most theoretical analysis in sociology and economics, when it dealt with technology at all, tended to relegate it to the status of a peripheral variable. By contrast, these scholars placed the patterns of technological change at the heart of their analyses. Gilfillan and Schmookler developed explanations of innovation.[34] Ogburn studied the relationship between new technology and societal values and structures. Their style stood in sharp contrast to internalist history. The demands of quantitative, systemic analysis common to both disciplines precluded attention to the design of individual technologies. For them, "technology" as a general socioeconomic force was more significant than individual "technologies."

Contextual history

Two books represent the third approach. Louis Hunter's *Steamboats on the Western Rivers* and Lynn White, Jr.'s *Medieval Technology and Social Change* created historical syntheses of technical design and historical context.[35] Both authors conceived of the internal design of specific technologies as dynamically interacting with a complex of economic, political, and cultural factors. Both historians—like Ogburn, Gilfillan, and Schmookler—stressed technology to an extent not typical in their fields. Historical analysis of the Middle Ages and of nineteenth-century America tended, in the main, to consider specific technologies as peripheral. For Hunter and White they were central. White's study created radically new interpretations of medieval social change in which a number of innovations related to mounted warfare, plowing, and

power-driven machinery played the central role. Hunter's *Steamboats* broke from the typical internalist model by his extensive attention to political, economic, and social factors related to steamboat transportation.

Two earlier classics can be considered forerunners of the contextual approach. Lewis Mumford's *Technics and Civilization* (1934) articulated a complex, technologically centered interpretation of civilization in the West.[36] While his division of the stages of civilization into the eotechnic, paleotechnic, and neotechnic periods was based on technological factors, the study differed from White's and Hunter's by sacrificing some depth of detail in favor of exceptionally broad hypotheses. Even granting this limitation, the work remains an early representative of attempts to create a historical synthesis of technology and nontechnological factors. Abbott Payson Usher's *History of Mechanical Inventions* (1929) combined characteristics of all three styles. The body of the work traces mechanical inventions in a comprehensive summation of internalist historical research. In the first four chapters, however, Usher articulates a general theory of innovation not unlike Gilfillan's. Like contextual historians, he argues for the integration of technological development within a broad cultural context.[37]

Methodological Profile of the Journal

The debate about method is reflected in the variety of methodological styles—and in changing patterns among them—of the 272 articles published in TC between 1959 and 1980. To summarize our findings in advance, of the three contributing scholarly traditions to SHOT only internalist history and contextual history continue to play important roles throughout the first two decades of the journal. Nonhistorical analysis begins strong, but except for the influence of economic models on TC's interpretation of innovation, it dwindles to insignificance. This is, in fact, why the rather vague cover term has been adopted. "Nonhistorical analysis" does not differentiate among economic, anthropological, philosophical, or literary analyses because, although all are found in the set of articles, their several disciplines are less important than the fact that they are not historical scholarship. It appears, in other words, as if SHOT's gradual maturation as a historical society rendered these nonhistorical contributions less and less appropriate for TC's pages.

To interpret the complexities of TC's methodologies a taxonomy was devised scoring all articles in two dimensions: general style and use of hypotheses.[38] The following survey of these taxonomic findings

Table 1
Methodological styles in *Technology and Culture* articles, 1959–1980

General Style		
Contextual	136	(50%)
Internalist	47	(17%)
Externalist	37	(14%)
Nonhistorical analysis	32	(12%)
Historiographical reflection	20	(7%)
Function of Hypotheses in Argumentation		
A priori	151	(56%)
A posteriori	121	(44%)

n = 272.

will help to understand the methodological substructure of each article, will provide an overall profile of TC's changing methodological styles, and, most important, will create a matrix within which these remarkably diverse articles can be "read" for their thematic content. Without help from such a differentiating taxonomy, it is virtually impossible to interpret thematic patterns. Before we analyze the articles according to these methodological categories, it will be helpful to see them in a single overview (table 1).

Three of the five methodological styles—internalist history, contextual history, and nonhistorical analysis—have already been identified as the three dominant types of technological research existing before 1959. A fourth style has been named "externalist" because it is the exact opposite of internalist research. Externalist articles study the context of technological events but do not discuss the design of function of the technologies in question. A fifth group of articles does not represent a style of research so much as reflection on the nature of such research itself. For this reason these "historiographical reflections" should be thought of as a metastyle. They are best understood as an extension of the vigorous private discussion of the field's intellectual identity already discussed.

Eleven early historiographical articles all appear in the first seven issues, dominating journal offerings in a fashion never again repeated. Even the fact that they make up half of the first twenty-one articles does not fully indicate the level of TC's early preoccupation with such reflection. The entire Fall 1960 issue was devoted to reviewing the five-volume *History of Technology* edited by Singer, Holmyard, and Hall

together with other recently published histories of technology from France, Italy, and the Soviet Union. It is possible, of course, that historiographic interest was not the only motive behind this remarkable concentration. It would be easier for scholars to write a short essay about their perception of the new field than to provide a full-scale article on relatively short notice. In fact, the articles are unusually brief, averaging ten pages compared with an average of over thirteen pages for all articles published before 1964. After this burst of publication the form disappears until 1970. Nine historiographical essays were published in the seventies, four in the cluster of 1974 and the other five separately. As noted, the appearance of the post-1970 articles, together with even more recent debate, indicates an ongoing interest of SHOT members in questions about the field's intellectual character.[39]

To see patterns of change among the other four styles it is helpful to break the twenty-one years of this study into three seven-year periods. The styles reveal, in their changing frequencies, some significant patterns of the role of hypotheses within each type. A scholar interacts with his or her peers most explicitly in two ways: by generating new hypotheses to interpret historical evidence and by critiquing or modifying existing hypotheses. In our taxonomy the category titled *"A Posteriori"* refers to articles whose authors are primarily interested in establishing one or more new hypotheses. The category named *"A Priori"* refers to articles whose authors explicitly respond to already-articulated hypotheses.

This perspective reveals the unique status of the nonhistorical analyses in TC. Only one of the thirty-two such articles generates new hypotheses on the basis of evidence reported in the article itself.[40] Nonhistorical essays tend to be summary statements of theories whose origins lie in other disciplinary communities. They can be seen to be the work of outsiders, not only because the vast majority of their authors were not SHOT regulars, but also because of the structure of argument in the articles themselves. It is clear that these articles are not addressed to SHOT members as a body of critical scholarly peers.[41] The marginal status of the style is further indicated by its virtual disappearance after the first seven years of TC's existence. Six articles appear in the middle seven-year period, and the number dwindles to two in the most recent period.

In constrast, the two largest clusters of articles—internalist and contextual—play an important role in TC's methodological development. In the first seven years they are nearly opposite in their style of argument. Seventy-one percent of the contextual studies generate new hypotheses, but they are almost always limited in scope to con-

clusions about a single event.[42] Thus Walter Dornberger's study of German V-2 rockets articulates hypotheses about the structure of the V-2 team and about relations with other German wartime institutions, but he does not attempt to expand these hypotheses beyond the V-2 case.[43] This cautious limitation of hypotheses is a sign of the youth of the field. These articles tend to be pioneering ventures into areas explored by few others. The questions being probed are by and large new questions. While the early contextual articles do not engage in much explicit dialogue, they serve the important function of identifying important thematic questions for the field. They do so, however, in a cumulative process by which highly specific hypotheses about individual cases begin to form a body of literature, which becomes more capable of generating explicit discourse as it becomes more extensive.

Early exceptions to the contextual *a posteriori* pattern demonstrate what is meant here by "explicit discourse." Robert Woodbury's attack on the myth of Eli Whitney as father of interchangeable parts manufacture, Milton Kerker's critique of the supposed independence of steam engine innovation from science, and Lynn White's assessment of Eilmer of Malmesbury's experiment with heavier-than-air flight all critique hypotheses that were articulated by earlier historians.[44] In so doing, they reveal the existence of clusters of scholars actively engaged in debate. It is this sort of mutually critical research that tends to be lacking in most early contextual articles. The number of historians adopting the contextual approach at this time was so small relative to the vast historical terrain open to them that most labored in research areas with no near neighbors. The historical process, described by Lynn White in his article on the nature of invention, could occur only in situations where the historian had peer critique.

Since man is a hypothesizing animal, there is no point in calling for a moratorium on speculation in this area of thought [i.e., history of technology] until more firm facts can be accumulated. Indeed, such a moratorium—even if it were possible—would slow down the growth of factual knowledge because *hypothesis normally provokes counter-hypotheses*, and then all factions adduce facts in evidence, often new facts. The best that we can do at present is to work hard to find the facts and then to *think cautiously about the facts which have been found*.[45] (my italics)

White's invitation to do "the best that we can do at present," to look for facts, and to "think cautiously" about them, appears to be an accurate description of contextual history in the early years of the journal.

The role of *a priori* hypotheses in internalist articles is a significant indication of the advanced state of internalist as compared with con-

textual discourse. Fourteen of the twenty internalist articles in the early years respond to some explicitly stated prior hypothesis. Thus Marjorie N. Boyer attacks the assertion that the Roman pivoted axle had been forgotten during the Middle Ages.[46] Like the articles by Woodbury, Kerker, and White, these fourteen reveal the existence of highly focused historical discourse. The fact that so many early internalist articles take this form reminds us of the relatively large number of semi-independent pockets of internalist scholarship in existence by 1959. TC's publication of some of their research served a dual function. On the one hand, the journal became a forum in which many previously independent groups of internalists could interact with one another.[47] On the other, the journal's policy of publishing research in different methodological styles opened the internalists to interaction with other, radically different, viewpoints about appropriate methods in the field.[48]

While the frequency of and the preference for *a priori* hypotheses remained roughly constant for internalist articles throughout the second and third seven-year periods, several shifts in contextual scholarship are noteworthy.[49] Contextual articles increased their share of the overall articles, from 41 percent in the first seven years to 53 percent in the middle period. During these years the pattern of contextual preference for cautious *a posteriori* hypotheses remained unchanged.

In the seven years after 1973, however, two remarkable changes occur which indicate a maturation of TC's universe of discourse as a body of contextual history. On the one hand, contextual articles become the clearly dominant style (68 percent). Even more significant is an almost complete reversal of the proportions of *a priori* and *a posteriori* hypotheses. After 1973 the share of contextual articles adopting an *a priori* use of hypotheses jumps from 29 percent to 57 percent. This shift, revealing as it does pockets of contextual historians engaged in explicit discourse, merits further attention. What were the questions that had begun to generate such dialogue? Three themes stand out: ten contextual articles analyze cases of technology transfer,[50] eleven treat cases of innovation,[51] and seven assess theories of the science–technology relationship.[52] The remaining ten treat independent issues.[53]

The significance of this change should not be underestimated. It is an unmistakable sign that the contextual approach to the history of technology has emerged from its years of infancy marked by individualistic interpretations of single cases and has entered a more mature stage of development. The cumulative effect of the *a posteriori* hypotheses articulated in TC has been to focus attention on several themes that transcend the case studies from which they originated. In a recent

historiographical article, Otto Mayr describes the communal process of historical research in precisely this fashion. "The historian's approach is fundamentally inductive rather than deductive; it *begins* with microscopic research in hopes that the empirical data thus gathered *will lead to generalizations on some higher level.*" (my italics)[54] The fact that well over half of the recent contextual articles engage in explicit shared discourse is a clear indication that the shift from microscopic research to higher-level generalizations has begun to occur. By their own research efforts, therefore, and with the help of the forum provided by SHOT, contextual historians have begun to define their intellectual identity in thematic terms.

The fourth methodological style found in TC, externalist history, provides added evidence of the dominant role of contextual history. Externalist research was slow to find its place in the overall array of articles. The ten articles scored as externalist in the first seven-year period tend to treat topics untypical of most TC research or to summarize prior research after the manner of nonhistorical essays.[55] In later years several patterns emerged. Externalist articles climbed from 9 percent to 18 percent of TC articles by the second period, and they held nearly that proportion, 16 percent, in the final period. In both periods their numbers exactly matched the number of internalist articles. The majority of the twenty-seven articles published after 1966 generated new hypotheses based on case studies. These *a posteriori* hypotheses are strikingly similar to the early contextual articles in that they tend to be limited to the case study in question. Thus Daniel Kevles's discussion of the post-World War II struggle for control of federally funded research offers hypotheses explaining why the military eventually prevailed. He does not, however, generalize beyond this case.[56]

These articles from the most recent fourteen years represent a new style of research in which historians study the ambience of technology without analyzing the design characteristics of the technologies in question. The emergence of this style is another striking example of the governing role of TC's dominant style, the contextual history of technology. The gradual accumulation of contextual studies has identified "the technological ambience," that is, a historical ambience precisely as it is related to technology, as a historical subject matter worthy of research in its own right. It is not surprising that the externalist style of history, taking the technological ambience as its methodological center of interest, should have developed some years after contextual studies. Before such research could become an accepted part of TC's shared universe of discourse it was necessary for SHOT members to

recognize its importance. The recognition appears to be one result of the growing maturity of the contextual tradition.

These chronological relationships among TC's three historical styles are another sign that SHOT began in a predominantly internalist climate. Contextual articles only slowly break from an internalist fascination with technical design abstracted from social context and only slowly generate thematic questions as foci for explicit disciplinary interaction. Externalist articles, a radical break from the internalist tradition, develop more slowly still and their development appears to be mediated by the increasing maturity of contextual research.

The numerical balance in recent years between internalist and externalist styles suggests that both have taken the role of valuable adjuncts to the central body of contextual history being published in TC. In their pure forms both styles contribute new insights. Given the newly dominant definition of the history of technology as that discipline which attempts an integration of technical design and its ambience, both remain dependent upon the vigor of ongoing contextual research for the creation of a single shared universe of discourse in which they can participate.

The Communal Character of Historical Research: An Interpretative Model

By this point it has become commonplace to refer to SHOT and TC as a universe of discourse. Before treating the contents of TC articles in subsequent chapters, it will be helpful to explain the expression by considering the communal nature of history in greater detail. The following model has emerged during the long process of analyzing the articles and designing taxonomies to reflect article usage. It reveals my own intellectual heritage in its use of insights from three traditions that have influenced my thinking; cognitive anthropology, general epistemological theory, and the special branch of epistemology known as hermeneutics.[57]

Five modes of historical scholarship
It is helpful to think of historical research as a process in which the individual scholar interacts with existing perceptions of the past. In the process five distinct types of interaction can be identified—the choice of a site for research, the determination of priorities among types of evidence, the use of themes to interpret evidence, the assessment of validity of evidence and of inferences from it, and the process of explicit dialogue with other members of the historical com-

munity. We will discuss the five interactions sequentially, but care should be taken not to infer that they occur in simple linear progression. Historical research is a dynamic process punctuated by moments of choice when one or another of the activities comes to central focus.

The first aspect of research is the choice of what we shall call the "site." By its very nature historical research takes place within a temporal and geographical context, which must be specified at least minimally. Historical events do not exist as atemporal or unearthly abstractions. Frequently the choice of specific boundaries for the research site is not the first decision made in a new research project. Boundaries will be shaped and reshaped according to the demands of the evidence uncovered during the entire process. Nevertheless, at some point the historian becomes decisive about the limits of time and place that will enclose the specific interpretation being advanced. Setting boundaries for a research site is, therefore, directly related to decisions about what evidence is central to the study and which hypotheses best interpret that evidence. To take a simple example, let us suppose that a historian of nineteenth-century American politics has uncovered evidence indicating that the political and economic dynamic usually called the post-Civil War reconstruction was less dependent on the war than on forces that began to be influential as early as 1830. The decision to stress the new evidence as a basis for a new look at "Reconstruction" will be accompanied by a decision to redefine the temporal boundary of the period.

The determination of priorities among types of evidence is a second choice facing the historian. The array of potential evidence is almost always greater than the amount practical for a given purpose. This imbalance forces decisions of priority. Some evidence will be treated as central, some as peripheral, and some as irrelevant. Thus, if a historian were to focus attention on evidence pertaining to James Watt's struggles with patent law, s/he would tell a different story than if central focus were given to the influence of scientific theory on Watt's inventive insights.[58] Conceivably, several historians with different evidentiary priorities could use identical bodies of evidence and still write radically different interpretations. Of course such prioritizing decisions will be affected by choices of site boundaries and of particular thematic questions of interest.

It can be argued that the third aspect of historical research, the thematic questions that the historian chooses to ask of the evidence, is the most important creative act of the entire historical process. Lacking thematic interpretation, history is reduced to a laundry list of "facts." Indeed, the historian's primary contribution to an under-

standing of the past depends on the questions s/he decides to ask. It can also be argued, of course, that the thematic questions that interest each scholar will influence decisions about site boundaries and and the relative priority of evidence. Thus, in the example used above, the decision to focus attention on evidence pertaining to Watt's legal struggle is rooted in a thematic question about the role of patent law in the innovation process. The fact that thematic questions are central, however, does not imply that they necessarily precede other decisions. It is quite possible that an encounter with surprising new material happens before the historian decides what questions to ask of it. Thematic questions are central because they provide the intellectual rationale that gives coherence to decisions about site boundaries and types of evidence. We can see, therefore, that the first three aspects of the historical process are intimately related acts of choice. Taken together, they are the core of the individual historian's creative contribution to the larger culture's understanding of the past.

The fourth aspect, the assessment of validity, is of less concern to us here even though it is an essential prerequisite for research. The historian cannot escape the responsibility of verifying, as thoroughly as possible, the validity of each piece of evidence used to advance an argument and the validity of any inferences drawn from that evidence.[59]

The fifth aspect of research, the dialogue between the individual historian and the historical community, occurs when new research is disseminated, whether in print, at formal meetings, or in informal conversation. The critical response of other historians, whose expertise enables them to assess the validity and relevance of new research, is an essential component of the process.

Were we to conclude this description of the historical process here we would imply that the first four aspects are primarily individualistic, that the significance of the historical community appears only in the dissemination process. To so imply would be a crippling oversimplification. On the one hand, it would suggest that "the historical community" is limited to professional historians and, on the other, that these historians form a community only on the level of explicit discourse. In fact, the historical community is much more extensive than the historians themselves, and its influence pervades every level of the research process in both conscious and unconscious ways.

Historical scholarship within a cognitive world view
To underscore the full reality of what we are calling the historical community, we must conceive of it as the sum of all persons, professionals or not, who in any way influence a culture's perception of its

past. More important, we must recognize that the very existence of this community is predicated on a cultural body of knowledge that includes and transcends the individual knowledge of its members. To explain the principle at work here it is necessary to introduce the anthropological theory on which it is based. Each individual decision by which the historian shapes new research takes place within the horizon of his or her previous understanding of the historical past. This previous understanding, received in the historian's earlier cultural education, functions as a set of assumptions about the past that will influence all subsequent decisions made during research. Finally, in the creative process of new research, the historian not only modifies his or her own previous understanding of the past but s/he also exerts some influence on the cultural community's understanding as well.

A central thesis of cognitive anthropology asserts that all individual activity occurs within a cultural ambience, a cognitive universe giving shape and meaning to the world. Multifaceted and complex, this cognitive universe is never appropriated by an individual in its entirety, nor does it function exclusively on the conscious level. James Spradley describes its role.

Most people do not stop to consider that they are continually using categories as they think and talk. Much of their knowledge about the classification of experience and the attributes that are used for this purpose are *outside of awareness. They believe that it is natural for the world to be divided up and structured in the way they have learned it to be.*[60] (my italics)

If a person did not share in some culturally learned universe of discourse that "divided up and structured" the world in some meaningful fashion, it would be impossible to think or to act. Such is the basic premise of cognitive anthropology.

The fact that no individual completely comprehends the whole of the culture's cognitive universe is of particular importance.[61] One's grasp of the cultural world view is incomplete because culture is learned in a finite manner beginning from a unique and limited starting point. In other words, each person's cultural perception is radically conditioned by personal history. It can be argued that the common cognitive universe in which individual members share exists as the "linguistic basis" for discourse. In the broad meaning used here, the "language" of a culture includes not only the normal linguistic dimensions of vocabulary, syntax, and usage, but also a whole set of norms and values, of beliefs and rules for behavior, which the individual must understand to be considered "fluent" in the culture.[62] Because the

cognitive universe of a culture is so centered in the human experience of communication, it is now helpful to expand our term "cultural ambience" to the culture's "shared universe of discourse." This cultural world view, which is first received passively, becomes the basis for all communication and indeed for all cognition. By participating in such a shared universe of discourse—both as recipient learner and as creative contributor—the individual becomes a full member of the culture's life process, a process in which the shared universe of discourse is continually modified through the creativity of its members.

This anthropological theory sheds considerable light on the interplay between the creativity of the individual historian and the larger historical ambience in which research occurs. The communal dimension of research is not based on the historical community seen as a collection of individual historians, as much as it is in the shared historical universe of discourse that serves as the basis for dialogue among the historians. In every stage of the research process the historian is in dialogue with that shared universe in precisely the same way that every participant in a culture lives in dialogue with his or her cultural universe of discourse.

Consider first how the historian is preconditioned by the common perception of history before ever beginning a research career. All of the history that s/he has learned—whether the formal research of professionals or the whole body of informal assumptions about the past and present which have been absorbed from one's family, the popular media, and so forth—operates as a set of biases preshaping the starting point for research. Like all other cultural presuppositions, these prejudices often exert influence without one's conscious awareness of their existence. They are the "natural" ways for the past to be divided up and structured. These unconscious prejudices, together with the explicit positions the scholar has come to hold about history, constitute the basis for all further research. This starting point is, in fact, a set of assumptions about the "orthodox" boundaries of time and place on the historical terrain, about the relative importance of various types of evidence, and about thematic questions that are worth asking.[63]

To speak of the "prejudices" of the historian is in no sense meant to be pejorative. To assume that the historian could approach the task of history unencumbered by prejudice (e.g., class, sex, national origin, race, culture, etc.) would be to assume that s/he was somehow outside of the historical process, having no personal history, no limiting starting point. Since this is impossible, such an assertion of objective and bias-free historical research would achieve nothing except to blind the

scholar to every sign of personal and cultural presuppositions. Hans-Georg Gadamer states the principle aptly.

A person who imagines that he is free of prejudice, basing his knowledge on the objectivity of his procedures and *denying that he is himself influenced by historical circumstance*, experiences the power of the prejudices that *unconsciously dominate him* as a *vis a tergo*. A person who does not accept that he is dominated by prejudices will fail to see what is shown by their light. . . . Historical consciousness in seeking to understand tradition must not rely on the critical method with which it approaches its sources, as if this preserved it from mixing in its own judgments and prejudices. It must, in fact, take account of its own historicality.[64] (my italics)

Given the importance of learned prejudices as the origin for new research, it is clear that any contribution will take the form of a modification of the existing universe of discourse. In the first instance, the historian modifies his or her own prior sense of history by choices made during research. In the second instance, s/he exerts some influence on the communal universe of discourse when publishing new findings.

Consider how this process might affect each of the three areas where historians must make decisions. It is possible that published research will question established geographical or temporal boundaries simply by articulating new ones. Insofar as the new definition of site boundaries is accepted by the historical community, the scholar will have modified existing assumptions. Research need not challenge existing assumptions. When new research accepts previous consensus about time or place boundaries, it strengthens the position of the consensus. The parallel challenge or confirmation of communal consensus about valid types of evidence is discussed by Howard Mumford Jones in an early TC article.

He who is trained to *scholarly orthodoxy* tends to look for what he wants in *the right places only*; and the right places have been in records and documents. . . . A peace treaty, a poem, a painting, a system of philosophy, an anthropological report possess academic respectability; a lever or an ink eraser do not. Historical evidence is, and has been, curiously "literary."[65] (my italics)

Finally, it is clear that the use of thematic questions already articulated by earlier scholars will reinforce their influence in the field, and that the creation of new themes will act as a critique on the existing set of interpretative hypotheses.

A new field of history, such as the emergence of a formal society for the history of technology, affects this process in two ways. In the first place, the preexisting set of assumptions about the meaning and shape of technology's historical past is more inchoate than is the case for older branches of history. As a result, the historian of technology has more freedom in shaping the boundaries of research sites, in determining priorities of evidence, and in choosing themes. S/he is more free precisely because there is much less historical discourse to be learned. On the other hand, the support provided by a well-articulated branch of history is to the same extent diminished. It is more difficult to construct a comprehensive and insightful historical interpretation without the help of an existing tradition and without the challenge of vigorous peer critique from many established scholars who are "near neighbors" to the area chosen for study. In the second place, the creation of a forum for scholarly exchange, such as TC and SHOT, will intensify this entire process. The process of publication—in TC and at SHOT's annual meetings in particular—becomes a major force in generating a shared universe of discourse that will continually influence, and be influenced by, new scholarship.

This communal model helps to clarify the assumptions and goals of this study of TC articles. Evidence presented earlier in the chapter strongly suggests that TC and SHOT have begun to create a community of historical discourse about technological change. The evidence suggests in turn that the interactions—between individual historians and their emerging universe of discourse—characteristic of such a community have been occurring in the twenty-one years covered in this study. It is not unreasonable, therefore, to consider the 272 TC articles as a single "text" in which we can discover an unfolding technological language, a language that reveals the intellectual character and world view of the new historical community and at the same time introduces us to the beginnings of a new way to interpret technological change.

A thorough sociological analysis of SHOT's attempts at disciplinary formation is not the primary focus of this study, although attention to the relationships, in the act of writing history, between personal and cultural assumptions and the content of research is important to understand the inner workings of the society and the formation of journal policy. Nevertheless it is the precise character of SHOT's historical *language* that remains the central concern.

This is a difficult matter. It can be argued that a detailed sociological analysis of SHOT leaders—of their links with existing traditions in the History of Science Society, the American Association for the Advancement of Science, and a variety of engineering traditions, of SHOT's

sources of funding, etc.—would reveal a conservative "world view" that bound the group to an inherently conservative "internalist" approach.[66] From this point of view contextualism, insofar as it demands a radical integration of Western technical designs with Western political and economic biases, would tend to be beyond the reach of SHOT's conservative perspective. In such a view, SHOT historians would be little more than Whig historians who chronicle the success story of Western technological achievements.

However, as will become clear in chapter 5, my study of TC's corpus of articles leads to a more complex interpretation. I argue there that TC authors have made impressive beginnings in the slow and difficult task of creating a contextual approach that has the potential to liberate the historical interpretation of technology from Whig history. Nevertheless, the detailed textual analyses of the next three chapters leads me to a critique of TC's blind spots which is not far from the more sociological analysis suggested above.

My intention in stressing textual, rather than sociological analysis is not to avoid the question of SHOT's biases, Whig or otherwise, but to permit the texts of TC's articles to speak for themselves. It is, finally, the *language* of technology's storytellers that exerts influence on the pervasive popular rhetoric of autonomous technological progress, either by legitimating it or by providing a liberating alternative. As I noted in the introduction, it is the cultural influence of "progress talk" that most concerns me and that led to this study. My conviction is that a fair and careful reading of the texts before us is the best approach to what is, at its core, a question of language.

The communal model provides several guidelines for textual analysis. As noted, the formation of new historical language takes place in the three kinds of creative decisions made during research: choices of site boundaries, decisions about priorities among types of evidence, and adoption of interpretative themes. The three will not be treated equally. We have already completed the primary analysis of evidentiary priorities by constructing the taxonomy sorting TC's historical articles into three types: those focused on the data of technical design alone ("internalist history"), those focused on contextual evidence alone ("externalist history"), and those attempting to integrate both types of evidence ("contextual history").[67] Subsequent chapters frequently use the matrix provided by this methodological taxonomy to shed light on thematic discourse in the journal.

Thematic interpretations receive by far the greatest attention in this study. The textual analyses of chapters 2 through 4 are designed to call attention to emerging consensus in TC, both expressed and implied.

Particular attention will be paid to what have been called *a priori* hypotheses because they reveal clusters of historians already engaged in explicit discussion of such issues. On the other hand, the relative youth of the SHOT community demands that we seek out patterns of usage which, while not yet developed into explicit discourse, have the cumulative effect of creating the basis for later such dialogue.

Care must be taken not to misunderstand the significance of the claim for thematic consensus being advanced here. The use of the expressions "consensus" or "emerging consensus" does not imply facile agreement among scholars on the march toward unanimity in their interpretations of technological change. "Consensus" here refers to the minimum of commonly shared language and assumptions that must serve as the basis for human discourse of any kind. As will be shown, the areas of linguistic agreement in TC sometimes suggest a high degree of ideological consensus, as in the consistent thematic treatment of the question of development, and sometimes the exact opposite, as in the sometimes contradictory interpretations of technology transfer.[68] Therefore the following reading of the "text" of TC articles serves three purposes: first, to provide evidence that historical discourse is in fact occurring in the forum provided by TC; second, to identify those thematic questions that have attracted the attention of significant numbers of the scholars who publish in TC; and third, to present a coherent overview of the interpretative language about technological change—with its ideological consonance and dissonance—that has begun to develop in the pages of TC.

Before turning to the thematic analysis in chapters 2 through 4 one task remains. As we have noted in our communal model, historians share in a discourse when they make choices of site boundaries for their research. What can we learn about TC's interpretation of technological history from their decisions in this aspect of the historical endeavor?

Land, Time, and Technology: Dimensions of Historical Terrain

The term "terrain" suggests the relationship of earth with maps. Whether or not the boundary lines of a map are based on obvious physical characteristics of the land, they necessarily represent some human consensus about boundaries. In like fashion, locating research in a specific time and place presupposes some set of temporal and geographical norms, presuppositions—either conscious or unconscious—about which places and times are historically more significant. Cumulatively, therefore, time and place choices within a community

of historians establish normative boundaries giving a particular character to the terrain of the past.

While geographical and temporal dimensions are essential for every branch of history, a given historical specialty may also designate topical boundaries. For internalist history of technology topical categories, based on traditional divisions of technology types, have often operated in this fashion. The value of topical taxonomies has been seriously questioned by some historians of technology, but their influence remains important and can be seen in the major divisions of bibliographies in the field.

TC's articles have been scored according to these three dimensions, and the evidence revealed by the resulting taxonomies indicates several significant patterns. On the one hand, they allow us to see the extent to which TC's shared universe of discourse is based on site convergence. On the other hand, the same areas of concentration reveal presuppositions about technology's historical terrain that suggest implicit biases about the definition of technology itself. We will consider the three taxonomies individually and then consider correlations between time periods and geographical areas. In conclusion, we will note several characteristics of the three historical styles—contextual, internalist, and externalist—that appear when they are correlated with the time-period taxonomy.

The geographical pattern seen in table 2 is significant and unambiguous. With very few exceptions, the articles locate their research in "the West" as it is commonly defined by the term "Western civilization." The United States and Western Europe account for 80 percent of all place references. This Western bias is further enhanced by two smaller clusters referring to the Middle East and the Mediterranean basin. Both areas are perceived to be the direct cultural and technological forebears of Western Europe. By contrast, references to Asia, Latin America, Australia, and Africa comprise altogether under 8 percent of the references.[69]

Given the Western bias in geography, it is not surprising that time periods tend to fit Western categorical norms as well. The beginning and end dates in the seven periods seen in table 3 have been set to approximate usage in the greatest number of articles. Thirty-eight articles cover several periods. Many of these attempt overviews of Western technology from prehistoric times to the present. Others trace the history of one type of technology through a sequence of dated events. The relatively small percentage of multiperiod articles confirms the validity of the seven time periods selected because the remaining articles can be scored within their boundaries.

Table 2
References to place in *Technology and Culture* articles

	Core references	All references
United States	114 (47%)	133 (35%)
Europe	32 (13%)	53 (14%)
Britain	29 (12%)	54 (14%)
France	11 (5%)	25 (6%)
Germany	8 (3%)	13 (4%)
Russia	7 (3%)	10 (3%)
Other European	12 (5%)	13 (3%)
Greece and Rome	9 (4%)	26 (7%)
Middle East	6 (2%)	22 (6%)
Asia	8 (3%)	23 (6%)
Latin America	5 (2%)	6 (1%)
Africa	1 (1%)	2 (0.5%)
Australia	0	1 (0.1%)
Totals	242 (100%)	381 (100%)

Table 3
Time periods of *Technology and Culture* articles

Ancient (5000 B.C. to 600 B.C.)	6 (2%)
Classical (600 B.C. to 400 A.D.)	10 (4%)
Medieval-Renaissance (400 A.D. to 1600 A.D.)	26 (10%)
Scientific and Industrial Revolutions (1600 A.D. to 1800 A.D.)	21 (8%)
Nineteenth century	70 (26%)
Twentieth century	75 (28%)
Several periods	38 (14%)
No time references	26 (10%)

n = 272.

The pattern shown by the articles falling into a single period is clear: the more remote the period, the fewer articles in it. Several aspects of these frequencies are noteworthy. The Middle Ages and the Renaissance have been collapsed into a single period because of the small number of references to the Renaissance. Although eighteen articles are devoted to medieval technology, the six centuries between the decline of the Roman Empire in the West and the beginning of the second millennium A.D. are virtually ignored. It is also obvious that the nineteenth and twentieth centuries are the overwhelming favorites.

Topical references to types of technology are diffuse. This is reflected in the remarkably asymmetrical nature of the subcategories in table 4. Some refer to one specific technology (the italicized subcategories), others to clusters of related types of technology. We find a handful of small clusters of articles on topics such as steam engines, machine tools, rockets, and the internal combustion engine. None has been the focus of shared discourse in the full sense of the term—explicit critical interaction among scholars about the same technology in the same place and time period.[70] The potential types of technology that could be researched by historians are so many that this scattered and unfocused pattern is not surprising. Because the absence of pattern does not permit us to draw any conclusions about the presuppositions of journal authors, the following analysis will be limited to geographical and temporal references.

The correlation of time and place patterns in table 5 reveals several further aspects of TC's site selection profile. The primary geographical referent for thirty-three articles is "Europe," understood as a cultural region of the world transcending national boundaries. Such references dominate the multiperiod survey articles and account for almost half of the articles in the medieval and Renaissance periods. After 1600, however, this international referent declines dramatically and is replaced by specifically national references. Britain and France, already well represented in the medieval period, become the dominant referent in the two centuries following 1600, the era of the scientific and industrial revolutions. By the nineteenth century, however, all European references taken together comprise only a small percentage of articles. This is due to the overwhelming popularity of the United States as a subject after 1800. The handful of references to Russia are, in the main, references to the Soviet Union after the revolution of 1917.

Table 5 adds a nuance to TC's bias toward Western and nineteenth- or twentieth-century technology. We find a geographical-temporal pattern moving in a single direction from ancient technologies in the Middle East, through the classical, medieval, and Renaissance tech-

Table 4
Technologies referred to in *Technology and Culture* articles

Metals	20
Weapons (conventional)	20
Chemicals	19
Land transport	17
Production systems	16
Agricultural innovations	15
Civil engineering	15
Water transport	15
Tools and instruments	12
Rockets	11
Steam engine	11
Internal combustion engine	11
Hydropower	10
Agricultural technology	9
Architecture	9
Air transport	9
Machine tools	9
Automata, clocks	8
Urban engineering	7
Textiles	7
Electrical technology	7
Weapons (nuclear)	6
Electric generation and transmission	4
Fuel	5
Mechanical power transmission	4
Computer	3
Telegraph	3
Telephone	3
Environmental technology	3
Mechanical feedback mechanisms	2
Musical instruments	2
Paper	2
Ceramics	1
Telemetry	1
Photography	1
Radio	1
Medical technology	1
Miscellaneous	65

italicized subcategories refer to one specific technology

Table 5
Correlation of time periods and core place references

	Ancient	Classical	Medieval-Renaissance	Scientific and Industrial Revolutions	Nineteenth Century	Twentieth Century	Several periods	Totals
United States				3	52	53	6	114
Europe	1		14	5	2	1	10	33
Britain and France			8	12	15	2	2	39
Germany			1			5	2	8
Russia					2	5		7
Other European			5	1	1	4	1	12
Greece and Rome		9						9
Middle East	5	1						6
Asia	1		2		5			8
Latin America					1	2	2	5
Africa								0
Australia								0
Totals	7	10	30	21	78	72	23	241

nology of the Mediterranean basin and Europe, to the "scientific" and "industrial revolutions" situated particularly in Britain and France, and finally into the contemporary technology of the United States.[71] As a community the authors tend to perceive the United States as the cutting edge of technology in the nineteenth and twentieth centuries and to ignore recent European technology almost as completely as they do all non-Western technology in any era. TC is an American journal, and the bias is to some extent natural. Nevertheless, the complete commitment to "the West" as *the* place of technology and the one-directional pattern just mentioned are evidence of a substantial cultural bias in the body of articles.

Apart from this bias, the absence of significant patterns is the most revealing characteristic of the map of the historical terrain found in TC. We find a map of an uncharted wilderness or, at best, a frontier. While it is true that most contributing scholars selected their sites within the Western unilinear bias, it is also clear that the historical terrain within that broad set of boundaries is so unmapped by prior scholarship that each new research site could be selected with relatively little consideration for preexisting canons of temporal, geographical, or topical orthodoxy. More than anything else, the three-dimensional map of site boundaries reveals the youth of the history of technology as a distinct discipline.

When the profile of article references across the time periods of Western civilization is correlated with the five methodological styles discussed above, we find several patterns that raise intriguing questions about the temporal and geographical predilections of contextual, internalist, and externalist historians of technology. Before looking at the data of table 6, let us recall the major conclusions about the three historical styles in TC. We noted above that the internalist and contextual styles are based on strikingly different methodological foci— the internalist's use of technological design as the organizing principle for research and the contextualist's use of the tension between design and ambience for the same purpose. The externalist style was seen to be dependent on a tradition of contextual history. Not only did it develop in the later years of TC's publication, but its primary organizational principle is the technological ambience itself. We noted that the concept of a technological ambience results from the cumulative effect of contextual research. It could be argued, therefore, that time periods dominated by contextual articles should also show a healthy percentage of externalist articles and that periods dominated by internalist history would be those in which the tension between technical design and the specifics of its cultural ambience had not generated

Table 6
Correlation of time periods and methodological styles

	Ancient	Classical	Medieval-Renaissance	Scientific and Industrial Revolutions	Nineteenth century	Twentieth century	Several periods	No time references	Totals
Contextual		4 (40%)	7 (27%)	14 (67%)	52 (74%)	43 (57%)	15 (39%)	1 (4%)	136 (50%)
Internalist	5 (83%)	6 (60%)	16 (62%)	3 (14%)	3 (4%)	6 (8%)	8 (21%)		47 (17%)
Externalist			2 (8%)	4 (19%)	13 (19%)	13 (17%)	5 (13%)		37 (14%)
Nonhistorical	1 (17%)					6 (8%)	5 (13%)	20 (77%)	32 (12%)
Historiographical			1 (4%)		2 (3%)	7 (9%)	5 (13%)	5 (19%)	20 (7%)
Totals	6	10	26	21	70	75	38	26	272

great interest among contextual historians. With these hypotheses in mind, it is enlightening to look at table 6's correlation of the three styles with the various time periods.

The internalist style clearly dominates the ancient and medieval-Renaissance periods. The classical period is marked by a more even division between contextual and internalist research. The four contextual studies indicate that their authors considered the Greek and Jewish cultural ambiences to be influential for the design of the technologies in question.[72] On the other hand, the contextual dominance of the periods from 1600 to 1900 is extraordinary and contrasts sharply with the minuscule proportion of internalist articles in the same two periods. It is clear that the tension between technical design and its ambience in these three centuries is of great interest to TC scholars. Not surprisingly, we find that externalist studies are almost nonexistent in the pre-1600 periods. On the other hand, they comprise a healthy 20 percent of the articles covering the periods from 1600 through 1900. The twentieth century reveals a unique pattern. Although contextual and externalist articles are still the most numerous, their dominance is muted by the presence of three equal-sized groups of internalist, nonhistorical, and historiographical articles.[73] The small size of our sample of articles does not permit us to draw firm conclusions from these patterns, but they do enhance our understanding of the characteristics of the three historical styles as they appear in TC. These patterns confirm our previous finding that the primary contrast, in terms of methodological style, is between internalist and contextual history, with externalist history following the pattern set by the contextualist writings.

Significant convergences in the geographical, temporal, and topical research sites of the articles could be a source of shared discourse for historians of technology. The evidence reveals that this has not been the case in SHOT's first two decades. It might be suggested that it is simply too early in the life of the discipline to find any significant shared discourse, but this is not so. As we shall see in the next three chapters, the themes that TC authors have adopted to interpret the history of technology provide evidence of some well-developed shared discourse. This is all the more remarkable in the light of the diffuse pattern of site selection found here.

2

Emerging Technology and the Mystery of Creativity

There is, indeed, no reason to believe that technological creativity is unitary. The unknown Syrian who, in the first century B.C., first blew glass was doing something vastly different from his contemporary who was building the first water-powered mill. For all we now know, the kinds of ability required for these two great innovations are as different as those of Picasso and Einstein would seem to be.

The new school of physical anthropologists who maintain that Homo *is* sapiens *because he is* faber, *that his biological differentiation from the other primates is best understood in relation to tool making, are doubtless exaggerating a provocative thesis.* Homo *is also* ludens, orans, *and much else. But if technology is defined as the systematic modification of the physical environment for human ends, it follows that a more exact understanding of technological innovation is essential for our self-knowledge.*
—Lynn White, Jr.[1]

With these words—the conclusion of his paper at the 1962 Encyclopaedia Britannica Conference on "The Technological Order"—Lynn White, Jr., captures much of the perplexity and wonder that continues to surround the mystery of technological creativity. How does it happen that human beings create structures previously unimagined? How does human imagination interact with the complexities of the technological status quo? And finally, how do these technical interactions—new designs with old—relate to the tangled web of culture and society? White spoke for many members of SHOT with his observation that "a more exact understanding of technological innovation is essential for our self-knowledge." This question, more than any other, absorbed the attention of TC's authors during the journal's first two decades, and it is no surprise that they form the foundation for the thematic analysis of this and the following two chapters.