THE DECLINE OF A TECHNOLOGICAL LEADER: CAPABILITY, STRATEGY, AND SHUTTLELESS WEAVING, 1945-1974

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In 1965 the Draper Corporation (Draper), the largest domestic textile machine manufacturer, was the 500th largest industrial corporation in the United States [9, July 1965]. Draper had been the world-wide textile machinery technology leader from the development of ring spinning in the 1870s and 80s through the development of automatic looms at the turn of the century and high-speed looms in the 1930s. It was a near monopoly producer of single-shuttle looms in its home market after the early 1930s until the mid 1960s. In the immediate post-World War II era, direct technological rivalry re-emerged as new competitors introduced shuttleless looms in mill trials. Among the early developers of a commercially viable shuttleless loom, Draper managers were particularly aware of the challenge posed by the pioneering developments in shuttleless weaving at Sulzer Bros., an engineering and science intensive Swiss manufacturer of electricity generating turbines.

While Draper was still the world's largest loom producer in 1967, it was increasingly obvious when comparing the wide variety of shuttleless loom prototypes displayed by the 30 exhibitors at the annual textile machinery trade show [21, p. 420], that the Draper shuttleless technology was falling behind in terms of technical performance. Draper had underestimated the competitive threat, particularly from Sulzer Bros. Why and how did the Draper managers stay with an ultimately failing technology development strategy for over 20 years?

The infusion of much-needed new resources and their mobilization within more effective strategies seemed to be at hand when Rockwell-Standard acquired Draper in the midst of one of the largest and most glamorous conglomerate mergers of 1967. Originally scheduled for the same day, Rockwell-Standard merged with North American Aviation shortly after

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the Draper acquisition to form North American Rockwell, the 28th largest industrial corporation in the United States [9, June 15, 1968]. (Although renamed Rockwell International in 1973, both corporate entities will be referred to as "Rockwell" hereafter.)

As the leading independent supplier of automotive components, Rockwell-Standard had previously pursued an aggressive growth strategy via "related diversification"--acquisitions restricted to metalworking and machinery manufacturing. From 1959 to 1969 the pace of its expansion quickened as the Rockwells (father and son) directed 30 acqusitions, but their concept of relatedness underwent a dramatic transformation. North American Aviation (NAA), the largest manufacturer of space vehicles and liquid propellant rocket engines, had been confronting near-term cutbacks in the space program as the Vietnam War escalated and the forseeable limits to lunar exploration were anticipated. A major entrant in more varied technological fields on a larger scale than any other company (including electronics, nuclear energy, and systems engineering), NAA was noted for its highly educated workforce with 600 Ph.D.'s and 16,000 engineers with technical degrees among its 89,000 employees. Furthermore NAA had developed its technologies in house as opposed to pursuing growth through acquisition. Dependent on government contracts for 95% of sales, NAA was seeking avenues to commercialization [4; 8, p. 23; 17, p. 172].

The Rockwell managers' vision was to marry North American's expertise with their company's commerical savvy. The remarks of one Rockwell-Standard executive reflected the headiness of those go-go years, but also the basic view of his company's gains from the merger, when he said, "Those scientific longhairs throw away ideas every day that should be useful to us. We're going to get out there and go through their wastebaskets" [17, p. 101]. From the first, both companies feared marketing failures of new products with high development costs so the initial conception called for the acquisition of going companies that could "easily be fed new technologies." From the point of view of NAA executives, they had acquired an "acquisition team" so that in effect they were going to be building "a series of facets (sic) to which we can append other new partners" [3, p. 160; 17, p. 172]. Approached and acquired during NAA merger negotiations, Draper was among the first such hook-ups, but by 1975 the spigot had run dry and the process of disengagement was begun. In that year Rockwell management put the Draper Division into a semi-liquidation mode, insuring the demise of existing U.S. capabilities for sustaining competitiveness in the development of weaving technologies. In 1982, with less than 1/4 the number of employees as at the time of the merger, the Draper Division was sold to private investors [24]. What went wrong?

Assessing the poor managerial performance and relative decline of many American manufacturing firms to their more successful European and Japanese rivals, analysts have tended to stress two central dynamics--outdated strategies ossified within stagnant organizational structures, and shorter time horizons induced both by capital market pressures and managerial practices [5, 7, 11, 18]. The next section of this paper will provide a brief historical overview of Draper's pre World War II business

strategies and developing organizational capabilities as they confronted the technological choices presented by shuttleless weaving. The third section will review the development of shuttleless weaving capability among the early technological rivals. The last sections will assess the role of pre and post merger strategic decisions contributing to the decline in Draper's competitiveness, and the way in which outdated strategies and short time horizons resulted in the demise of Draper's organizational capability.

A Historical Review of Key Strategic Choices at Draper

Soon after marketing the automatic *bobbin*-changing loom in 1895, Draper became the dominant firm in the industry and built a plant sufficient to supply the national loom market. Draper was a national leader in industrial research in the first decade of this century. Having established considerable market power and first mover advantages, a family split developed over the strategic choice of either standardizing loom models or sustaining high development costs associated with further variety in design and the proliferation of new loom models. [Parts of this section summarize 15 and 16.]

In a managerial struggle for control that proved fateful for the trajectory of Draper developmental strategy thereafter, ousted officials and departing employees had been responsible for one-third of all patents ever assigned to the company from its origins in 1816 up to that time. The remaining top executives turned to a more adaptive strategy, based on less risky development. They successfully mined the lucrative gains to be made from continual incremental technological improvements and pushed to improve manufacturing productivity and secure economies of scale as protection from competitors. They cut back on loom experimentation and concentrated on improvements adaptable within the enduring basic loom design.

In an early version of the "razor and blade" marketing strategy, Draper priced new looms low relative to production costs in order to facilitate their widespread adoption and inhibit competition in the primary market for new looms. At the same time the company increased markups in the secondary market for parts and accessories with the highest mark-ups on the items least essential to loom operation. In this manner, profits were maximized as costs were reduced relative to sales gained from both the primary and secondary markets.

Ironically, the most significant competition faced by the Draper Corporation came from the Hopedale Manufacturing Company, a company founded in 1912 by the dissident Draper family members and inventors. With only one-fifth the capacity, the Hopedale Manufacturing Company originally attached automatic mechanisms to operating looms but later specialized in customized new automatic looms. Lacking comparable scale economies, the new competitor could not survive both the rivalry and the 1920s industry slowdown. Liquidating assets in 1927, President Clare H. Draper sold 147 patents assigned to the Hopedale Manufacturing Company to the Draper Corporation for $1, but he also became a member of the

Draper Board of Directors, Manager of the "Experimental Works," and gained a sales management position for his son.

Draper's private research efforts were the largest in the industry, still the acquisition of outside talent for innovation remained significant for the development of weaving technology and new Draper products. The Hopedale Manufacturing Company patents provided key elements for silk and worsted automatic looms marketed in the 1930s. More significantly, Clare H. Draper directed the development of the X-model high speed loom after 1927 based on the integration of rival technical advances made in the two companies.

First marketed in 1930, the heavier X-model was designed to run 20% faster and replace the E-model loom. The sales of these two standard models accounted for three-fourths of all Draper sales from 1909 to 1934 [21; 2]. Throughout the 1930s, however, the market share of cloth made from continuous filament yarns, principally rayon, increased dramatically, and so did the importance of adding a continuous filament high-speed loom to the Draper product line.

Draper first marketed an automatic *bobbin*-changing loom for weaving rayons with little success as early as 1921. Another niche competitor, the Stafford Loom Company, successfully wove the more break-prone rayon yarns with an automatic *shuttle*-changing loom. Purchasing the Stafford Loom Company in 1932, and utilizing Stafford patents, capacity, and personnel, Draper immediately marketed the Stafford loom as their own. Building upon the acquired technology, Draper developed rayon automatic *bobbin*-changing loom models.

With the development of synthetic fibers, the two fundamental market segments were looms weaving continuous filament yarns and looms weaving spun yarn, the latter now including both natural fibers and filament cut to fiber lengths appropriate for spinning. The sales of XD looms were 38% of new loom sales from 1939-1942, and were one-third of output from 1944-1959 [2].

Shuttleless Weaving and Organizational Capability

In 1927 Rudolf Rossman, a textile engineer in continental Europe's largest textile mill, completed five years of patent research into designs for replacing the traditional shuttle, the fundamental constraint limiting the speed of loom operation. Rossman applied for his first patent the following year, built his first projectile shuttleless loom prototype in 1930, and secured financial backing. Sulzer Bros. assumed the major financial interest in 1933, moved the loom experiments to a nearby Swiss location, and secured the exclusive right to manufacture the shuttleless loom by 1942 [21, pp. 366-87, 565-68].

In 1945, the machine tool manufacturer Warner & Swasey (W & S) experienced a dramatic increase in idle capacity as its machine tool orders collapsed with the close of the war. Following extensive textile patent research, W & S approached Sulzer seeking to license the latter's shuttleless weaving technology. Sulzer was eager to recoup some of its development costs and lacked mass production facilities and experience. Sulzer's machine

design was based on the metric rather than the inch system. The latter was necessary for selling to American mills, the largest single loom market.

Recognizing a need for an alliance with an American mass producer, Sulzer had approached Draper about licensing its rights for manufacturing a projectile shuttleless loom. Thomas West, President of the Draper Corporation, sent an engineer Walter Budzyna to Brazil to investigate a flexible rapier, hairpin weft-insertion shuttleless loom.[2] West initiated a 3-person development project in 1946 to design a loom on the same principles, which became the forerunner of the DSL (Draper ShuttleLess) loom. Draper had declined to respond to Sulzer's initiatives and Sulzer licensed Warner & Swasey in 1945 [21, pp. 388-92].

Sulzer focused its development strategy on weaving plain cotton cloth on shuttleless looms. W & S, on the other hand, chose to develop a shuttleless loom for weaving stronger wool and worsted yarns which required less demanding mechanical precision. The W & S strategic decision meant simultaneously developing multi-color weft capability which was necessary for the more fashion conscious wool market. W & S was thus avoiding direct competition with Draper in the much larger single-shuttle (single weft color) cotton loom market. However, the two allied firms, W & S and Sulzer, were pursuing divergent development programs.

In the product development race that ensued, W & S developed a commercial loom first in 1953, albeit with a limited production capability. In the six years of production they sold little more than 1000 looms [21, p. 414]. Slower to market, Sulzer's sales, all outside the U.S., totaled 2500 by 1959. In that year, Draper began to sell the DSL loom. Draper invested over $2 million to retool for DSL manufacturing, but because of the limited range of saleable cloth for which it was suitable, research focused on increasing its versatility.

The competition from Draper played a significant part in W & S's decision not to invest $1.5-2 million to scale up for mass production of projectile looms as Sulzer had been demanding. Instead, W & S spent nearly an equivalent sum to buy out the Sulzer licensing agreement. In addition Sulzer insisted that W & S increase the size of the projectile in their loom so that the mass was sufficient to carry across wider looms (over 200 inches.) Sulzer had accurately identified this change as essential for establishing the loom's cost competitiveness (see below,) but it would require a costly redesign of W & S's entire weft insertion system along with complementary redesign of all other loom motions. In part, because W & S

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[2]The Sulzer projectile loom in fact used a miniature shuttle, called a gripper shuttle, to carry the weft yarn across the shed. Like a conventioanl shuttle it is hammered across the loom. Since the gripper shuttle weighed less than 10% as much as a conventional shuttle and carried a single strand of yarn from a supply package mounted on the side of the loom instead of carrying a bobbin along with it, its potential speed was much greater. In a rapier loom, a rod carries the weft yarn through the warp shed. The DSL used two flexible rapiers, one mounted on each side of the loom, which entered the shed simultaneously, meeting in the middle to transfer the weft from one to the other. In effect the weft yarn is in a hairpin formation at the point of transfer and the trailing end must travel doubly fast as the second rapier is withdrawn to complete the weft insertion.

had failed to create dedicated facilities for lower cost loom manufacturing, higher profit rates in their long established machine tool divisions justified shifting capital allocations back in that direction.

As Sulzer began shipping its looms directly to the U.S. market in 1960, Draper responded with another side of what was in effect a dual strategy to confront its new competitors. Besides the DSL loom, Draper improved the verstility of its conventional looms by creating the X-3 loom, a "mongrel," designed to replace both the X-2 and the X-D. The X-3 loom was the first model that could be adapted relatively cheaply for weaving either spun yarns or continuous filament yarns. In practice, mills did not utilize this versatility as much as they anticipated because of the costs of adapting the rest of the mill production to the changes in fiber.

Nevertheless, sales of X-3 looms led the steady growth of overall Draper sales from 1960 to its cyclical peak year of over 18,000 looms in 1965. Sales of X-3 looms rose to a high of 70% of sales in the peak year [2]. In that same year, Draper spent the largest amount on capital expansion in the history of the company. Over half of the $10 million capital expenditure was on the Thomas West foundry, a state-of-the-art, highly integrated and automated foundry. A serious design mistake was made in attempting to standardize the size of moulds in casting to facilitate movement down the line and maintenance costs were underestimated. Small errors and irregularities led to so much downtime that despite projected throughputs of 700 moulds a day, the actual throughput was under 100 moulds per day during the first year. Although the unanticipated start-up foundry costs had little overall effect on Draper's price competitiveness, they continued to create difficulties in achieving budget projections, an increasingly important managerial concern under Rockwell ownership.

Who is Responsible?

"Who is responsible for insuring that a company continues as a technological leader?" asked William Turner in 1951, early in his management trainee program at the Draper Corporation. Turner addressed his question to Thomas West, President of the company and Turner's mentor. West replied that responsibility belonged to the President of a company. Turner followed up his first question with another: "How does he go about doing this job?"

West responded that he had asked a similar question of President H. B. Bristow Draper, the last family member to head the company and his immediate predecessor. President Draper had answered, "It helps to keep a million dollars in the bank. A million dollars can go a long way toward buying any new technology" [25]. The problem with this answer is that maintaining ample cash reserves was the easy part. The difficult part lies in knowing which technologies to pursue and the amounts and types of resources that should be devoted to their development over time. However, it is not surprising that H. B. Bristow Draper and Thomas West would take it for granted that they and the Draper organization would have the capability and the resources to identify potentially superior technology. If their recognition of superior technology lagged behind their rivals, the

greater resources at Draper could easily make up for lost ground when the need to do so became obvious. After all, had not the superior market position of the Draper Corporation prevailed in their competition with, and the ultimate absorption of their main rivals, the Hopedale Manufacturing Company and the Stafford Loom Company?

So the question of competitive failure at Draper divides into two questions: why did Draper select and maintain development of a technological alternative that turned out relatively limited in productive potential and why did the organization under Rockwell management throw in the towel when they were still the strongest rival to Sulzer in the world market?

Thomas West passed up the opportunity to develop the Sulzer technology because of two main reasons: First, he accurately surmised that it would take a longer period of further development before Sulzer's projectile loom would be commercially competitive compared to the time it would take for Draper to market a commercially acceptable shuttleless loom based on the flexible rapier principle. Second, he did not want to modify his manufacturing capacity in order to construct the Sulzer loom out of the alloyed steel required by Sulzer's specifications.

In sum the Draper attitude from the end of World War II until at least the mid-1960s was that the Sulzer loom was "over engineered," in that its increased precision in operation was at too high a required increase in price relative to improved performance. Draper continued in its emphasis on modernizing mass production methods and developing potential scale economies, but building upon existing capabilities turned its product development strategy toward comparatively incremental technological change in both conventional and shuttleless weaving.[3]

For over twenty years the Draper strategy held up. As late as 1962 the Draper shuttleless loom increased loom speed and weaving labor productivity by nearly 40%, while the Sulzer loom on comparable widths increased speed by 50%, and productivity at a greater rate as it decreased yarn breakage to a significantly greater degree. But at a price of 5 times the comparable fly shuttle looms, the Sulzer model was not yet cost competitive with the Draper X-3 looms that could be fitted with attachments available since the 1950s [10, pp. 53-58]. These attachments saved on the weave room labor involved in handling filling yarn. The Draper shuttleless DSL loom was cost competitive on the range of cloths for which its production was suitable because its lower manufacturing costs allowed it to be priced at only one-third the Sulzer loom's price (or about 1 2/3 the price of the X-3) [20, p. 251]. From 1959 to 1969 Draper shuttleless loom sales

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[3]Piore and Sable have identified the rigidities of the traditional mass production system, as opposed to a more flexible craft system, as a source of failure of U.S. manufacturing firms [18]. They have provided the framework guiding several case studies noting the sharp contrast between failure at Draper and the successes of specialized German textile machine manufacturers producing niche markets [7, 12, 19]. This comparison is seriously misleading because it was not small, progressive, "craft" producers who dethroned the Draper Corporation, but Sulzer Bros. which took pride in its refinement and extension of U.S. mass production methods when it finally scaled up for volume production.

lagged only slightly behind Sulzer's looms sales of 17,500, the former exclusively and the latter mostly in the U.S. [2; 21, pp. 416, 422].

By the late 1960s Sulzer had successfully achieved productivity increases that began to erode Draper's market share. Beginning with wide sheeting, Sulzer discovered it could increase loom width by 150% (up to 213 inch width) and lose only 29% of the loom's speed. The difference in production was over 300% greater output than when manufacturing similar cloth on shuttle looms [20, p. 254; 23]. The flexible rapier principle could not sustain comparable speed advantages as loom width increased. Between 1969 and 1975 Draper sold 8,000 shuttleless looms, while Sulzer sold 40,000. By 1975 Sulzer's leading share of world-wide shuttleless looms in place was 17% and Draper's was 7% [2; 21, pp. 422, 427, 432]. Ironically, Sulzer was able to adapt its staple market cotton loom relatively rapidly for production of cloth made from different fibers and with multi colored weft, in large part because of the technological achievements resulting from W & S's divergent development path. Their pattern paralleled in an accelerated fashion, Draper's product development evolution for the E and X model looms, where success in volume production of a relatively specialized machine was followed by a broadened product line and then reintegration of technical capabilities within a relatively more versatile loom.

Yet the potential market still was largely untapped in 1975 since shuttleless looms were less than 10% of the world stock of looms [21, p. 432]. Draper still had fundamental organizational strengths--a loyal customer base and a national sales force, along with product development and manufacturing experience--upon which to further develop the organizational resources necessary to respond to the new challengers. But that was exactly when a change in ownership meant that new managers would chart Draper's course.

Rockwell's Promise and Draper's Demise

Rockwell purchased Draper on the accurate expectations that the weaving equipment industry would be a growth industry. However, it expected to improve on Draper management's ability to select and develop promising technologies, and in some ways did improve its strategic flexibility by increasing the speed and range of new product development. At the same time, Rockwell's business strategy and practices eroded Draper's operational effectiveness. In practice, Rockwell's technology transfer programs were underdeveloped and their potential, whatever their limitations, were undermined by stronger pressures for short term results.

By the early 1970s Rockwell was a financially oriented company primarily run by a highly integrated, planning staff. Rockwell's strategy of conglomerate growth, common at the time [14], sought high earnings per share and predictability of earnings so that given the stock price to earnings multiple, the basis for financing planned expansion would be realized. Rockwell's emphasized the central importance of managers realizing projected near-term cash flows.

The inability of Draper managers to meet their budget projections in a rapidly changing environment led to rapid turnover in top management at

Draper. From 1969 to 1976 there were five different presidents at the Draper subsidiary, and with three changes in divisional organization, there were four different corporate officials to whom he directly reported. The immediate pressures to improve near term performance did not provide a basis for securing a sustainable long-term position. In particular, good product development work was undermined as meeting cash flow projections sometimes meant pushing incomplete and second-quality products out the door in order to secure a bill of lading.

Finally, and most importantly, the expectation that formal scientific training could make rapid progress in the "antiquated" textile machinery industry was seriously mistaken. Rockwell's technology transfer policies evolved in three stages: internal consultation; a "brain transplant," wherein the installation of a new general manager acting as a "technology driver" was hoped to insure receptivity to otherwise easily transferred technology; and finally the recognition that a critical mass of technologists were required in place within the technology receiving division to insure the commercial viability of new technology products.

The former Chief Engineer of the Apollo Project headed a textile study directly budgeted at over $500,000, with extensive indirect support, that yielded little impact on product development at Draper. One example that crystalizes the overall limitations of internal consulting was the effort to develop a detector that could indicate which warp yarn was broken. The Rockwell engineers responded confidently that they could develop such a mechanism in months if not weeks. But when they studied the problem they discovered the great complexities of identifying the warp yarns on a 118 inch loom with 100 warp yarns per inch and a total of 11,800 warp yarns. The *coup de grace* was that the new mechanism had to compete with an existing detector that indicated a warp yarn was broken, but could not identify which one--it sold for $37. The Rockwell engineers were inexperienced in dealing with such cost conscious technical problems, given that their crowning achievement was the "success at all costs" direction of the Apollo moon shot. Needless to say, the Rockwell engineers never got back to the Draper people with a solution to their problem.

The critical mass of upgraded technologists was never achieved during the entire history of the Rockwell ownership of Draper. Only one aeronautics engineer was ever transferred to the Draper Division. Interestingly, this single transferred engineer left rocket design for a knitting machinery division in 1972, before becoming head of research and engineering at Draper in 1976. He dicovered a basic similarity in both industries when applying his engineering skills to evaluating tradeoffs in design choices, but it took "three years before (he) really understood" the balance between good engineering and cost, relative to industry performance standards [13]. Whatever the expectations for "technology transfer" within Rockwell's overall strategy for expansion into textile machinery, no significant long term integration of technical personnel was ever attempted, although the Sulzer success indicated its potential effectiveness [On the importance of the "receiving" mechanism see 6.]

In the only significant attempt by Rockwell at a "brain transplant" at Draper, Robert Page was made President in 1970. Page was an experienced

General Electric plant manager known for tight fiscal controls, but he was also a non-degreed engineer, holding several patents, including one winning the prestigious GE Coffin award. Typical of other conglomerate acquisitions, the only substantial transfers into Draper were of accounting techniques and financial practices and accountability. Page installed twenty fast track MBAs, none over 30 years old, into key positions as financial analysts, business planners, and manufacturing middle managers. At the same time, he also promoted career Draper managers to aggressively push new product development projects. Although not staying long enough to see the results, the projects Page authorized led to three new shuttleless looms in less than three years, including the DML projectile shuttleless loom.

Draper brought Erwin Pfarrwaller, Sulzer's top mechanical engineer and the main inventor of the projectile loom, to examine the DML, a Sulzer-type loom. Pfarrwaller's assessment allayed Draper management concern's about patent infringement and orders for 112 DML looms were obtained from Cannon Mills. An $18 million capital expenditure program had previously won approval from the Corporate Divisional managers and $7.5 million had already been spent on modernization, mostly for upgrading DSL manufacturing capacity. However, these plans included spending $10 million to scale up for DML production, and this last project lost support at the critical final stage before implementation.

The DML sales plan projected a three-year negative cash flow, although its author genuinely expected five years before showing a positive cash flow. But the timing was disastrous as Rockwell managers were made fully aware of the daily deterioration in Rockwell cash flows in 1974, which at its worst reached a negative cash flow of $1 million a day [1, 13]. Rockwell was unwilling to support the planned technological catchup program at Draper, largely because of the extremely short time horizons created by the liquidity pressures stemming from losses at other recently acquired operations and the developing recession. In addition, Draper managers feared that price competition from Sulzer would diminish cash flows from DML sales below their projections.

Further technological development at Draper was abandoned by 1975, as Rockwell laid off, among others, 100 employees in the Research and Engineering Department, one-half of the entire staff. Subsequently used strictly as a cash cow to finance other emerging technology divisions within Rockwell, Draper's organizational capability was dissipated faster than if it had been an independent firm, and the company's role as a major textile technology player was at an end.

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