

ISSUES AFFECTING THE DECISION TO  
INCORPORATE NEW TECHNOLOGY IN A  
VEHICLE PROGRAM

by

C. DAVID WRIGHT

B.E.E., General Motors Institute  
(1979)

M.S.E.E., Stanford University  
(1982)

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Signature of author: \_\_\_\_\_  
Alfred P. Sloan School of Management  
May 10, 1991

Certified by: \_\_\_\_\_  
Thomas J. Allen, Jr.  
Thesis Advisor

Certified by: \_\_\_\_\_  
Edward B. Roberts  
Thesis Reader

Accepted by: \_\_\_\_\_  
Roger A. Samuel  
Director, Management of Technology Program

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ABSTRACT

Technological innovation has become an important competitive tool in today's automotive industry. A successful innovation encounters many obstacles on its path to production implementation, and by definition must overcome each obstacle to succeed. This thesis examines the importance of innovation to the automotive industry, the nature of innovation, and those issues that affect the decision to incorporate new technology into a production-intent vehicle program.

A questionnaire-based survey of participants in seven different advanced development projects within an automotive manufacturer is analyzed. Response differentials are calculated between successful projects and unsuccessful projects. The perspectives between operating group and staff respondents are also compared. The results of the survey, together with personal interviews, are then used to suggest various methods that could improve the effectiveness of R & D projects within the company.

Thesis Supervisor: Thomas J. Allen, Jr.  
Title: Professor of Organizational Psychology  
and Management

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# CHAPTER 1

## INTRODUCTION

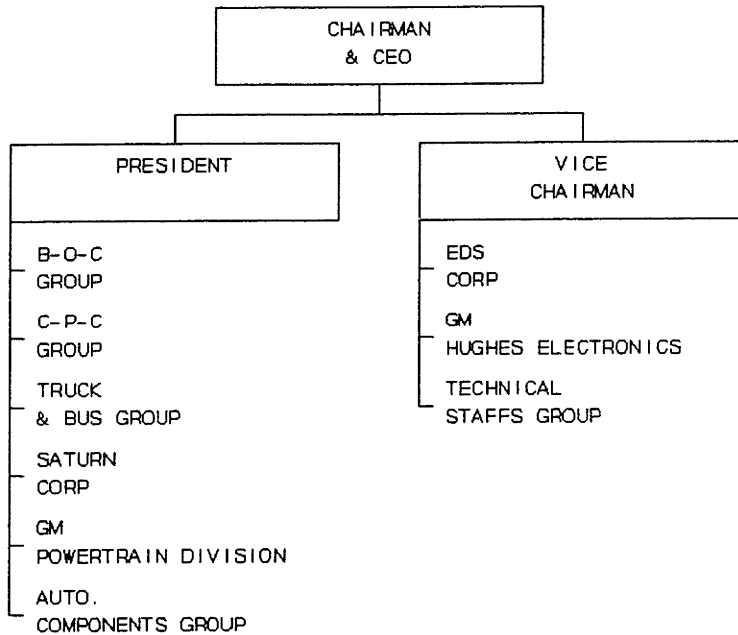
Within established firms and product lines, the introduction of new technology is often a difficult process. This process can be even more difficult when a variety of organizations within a company are involved in the process of technological innovation. Such is the case within the automotive operations of General Motors, where there are many different R & D groups that attempt to develop new technologies for the corporation's products and processes. The largest grouping of R & D projects can be found at the corporate Technical Center, which is home to the GM Research Laboratories (GMR), Design Staff, Advanced Engineering Staff (AES), and Current Engineering and Manufacturing Services Staff (CEMSS). In addition to the Technical Staffs, the vehicle operations (Chevrolet-Pontiac-Canada [CPC], Buick-Oldsmobile-Cadillac [BOC], Truck and Bus, and Saturn) and the component divisions of the corporation perform varying degrees of advanced development as well. Figure 1-1 is a simplified organizational chart of GM which illustrates the relationship between these various groups.

Because of the size, scope, and uncertainty involved in such a wide variety of development organizations and projects, it is very difficult for GM management to develop a

**Figure 1-1: General Motors Organization Chart**

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comprehensive understanding of the issues that contribute to successful technological innovation within the corporation. Simply examining the technical characteristics of development projects provides little insight into the problem. Virtually all projects, both successful and unsuccessful, contain characteristics that are desirable and seem within reasonable reach of attainment given a sufficient level of development effort. This should come as no surprise, because early resource allocation procedures eliminate projects that do not meet these basic requirements.

Attempts at technological innovation encounter many obstacles, both technical and organizational, throughout the



development process. Successful projects, by definition, are the result of overcoming each of these obstacles, any one of which could have halted the innovation process. An understanding of the factors that allowed successful projects to overcome these obstacles would prove beneficial in selecting and managing advanced development projects.

Out of the large number of advanced development projects within GM, only a portion are selected to be included in production vehicles. Once this decision has been reached, the project takes on a different perspective as it moves from the advanced development arena to the production environment. Development efforts become more focused and closely coordinated as the project concentrates on a specific application rather than generic technology development. Additional resources are allocated, production schedules are developed, and all of the concerns of high-volume production must be addressed: manufacturability, quality, reliability, safety, and profitability. Therefore, the decision to incorporate new technology in a production-intent program is a critical point in the progress of a successful innovation. This thesis will examine the various issues that influence the outcome of this key decision.

The basic characteristics of technological innovation have been the focus of many previous studies. These studies have examined the relationship between "technology push" and "market pull," the relationship between innovation and

science, the destructive aspects of innovation, and the conflict between innovation and the drive for increased productivity. An understanding of these characteristics is required for effective management of advanced development activities.

A second dimension of the innovation process involves the quantitative aspects of the innovation and its development. These issues include the technical performance of the innovation, marketing, quality, reliability, cost, capital, and project timing. The quantitative aspects of a project represent the major focus of most management efforts: develop a technology that offers performance advantages the market will accept while meeting the desired quality, cost, and scheduling goals.

A final dimension of the innovation process revolves around the organizational structure and managerial process. This dimension includes factors such as critical function staffing, the use of multi-functional teams, and bridging mechanisms to encourage technology transfer. Previous research has documented the importance of each of these issues in successful technological innovations.

These three dimensions of the innovation process within seven of General Motors' development projects will be examined. Each project had its beginnings in a corporate advanced development activity. The projects can be divided into two groups: those that resulted in production commit-

ments for implementation (successful) and those that did not obtain a production commitment (unsuccessful). The terms successful and unsuccessful are meant to apply only to the effort to include the new technology in a particular targeted vehicle program. As stated in Chapter 5, most of the projects termed unsuccessful for the purposes of this study often had success in follow-up programs or are continuing in the belief that the technology continues to be worth pursuing. This narrow view of success and failure was taken in order to focus attention on a particular application of each technology under development.

Through a questionnaire-based survey, the perspectives of individuals within both operating and staff groups were obtained in an attempt to identify those issues that most strongly influenced the decision on whether to incorporate the new technology into a production vehicle program. By combining the results of the original research with academic knowledge of the innovation process, a better understanding of those issues that affect the decision to incorporate new technology into an automobile within General Motors is attained.

## CHAPTER 2

### THE IMPORTANCE OF TECHNOLOGICAL INNOVATION

#### DEFINITIONS

Before embarking upon a detailed study of technological innovation, it is important to define two terms: technology and innovation. Although both words are commonly used, there are some important insights that arise from a careful examination of their meanings.

Webster defines technology as "the totality of the means employed to provide objects necessary for human sustenance and comfort."<sup>1</sup> This definition accurately reveals that technology is something that surrounds and encompasses virtually everything that we do. In the foreword to *Innovation: The Attacker's Advantage*, Robert Waterman, Jr. states that "We are all technologists, every one of us who knows how to do something a certain way and uses tools to do it, be they pencils or personal computers, machine tools or video screens."<sup>2</sup> Viewed in this fashion, technology encompasses everything from the simple skills we

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<sup>1</sup>Webster's *New Collegiate Dictionary* (Springfield, Massachusetts: G. & C. Merriam Company, 1974), p. 1197.

<sup>2</sup>Richard N. Foster, *Innovation: The Attacker's Advantage* (New York: Summit Books, 1986), p. 15.

learn in childhood to the most sophisticated electronics and biotechnology.

Similarly, Webster defines innovation as "the introduction of something new."<sup>3</sup> By focusing on the *introduction*, rather than the *discovery* of something new, a distinction is drawn between innovation and invention. "Innovation, as distinct from an invention or technical prototype, refers to technology actually being used or applied for the first time."<sup>4</sup> This difference between innovation and invention is extremely important, because it is the commercial application of an invention that provides economic benefit to a firm, not the act of inventing it.

For the purposes of this study, technological innovation will therefore be viewed as the commercial application of a new means of accomplishing a task in either the manufacturing process or the end product. Within that context, the issue of its importance to the automotive industry can be addressed. The key question to be considered is whether or not technological innovation is an important competitive factor in today's automotive industry. If the importance of innovation can be established, then efforts to understand the decision processes that surround

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<sup>3</sup>Webster's *New Collegiate Dictionary*, op. cit., p. 595.

<sup>4</sup>James M. Utterback, "Innovation in Industry and the Diffusion of Technology," *Science*, February 15, 1974, Vol. 183, p. 621.

successful and unsuccessful attempts to innovate become valuable.

## COMPETITIVE PRESSURES

The domestic automobile industry is under serious competitive pressure from foreign competition. Japan's share of the United States auto market has increased from 19.6% in 1980 to 27.7% in 1989.<sup>5</sup> Table 2-1 shows the top-selling passenger cars in the United States in the 1990 model year.<sup>6</sup> The Honda Accord has been the best-selling model in North America since 1989, a position that had been the exclusive domain of General Motors or Ford for the past eighty years.<sup>7</sup>

As the historic market leader, General Motors has seen its share of the U.S. car market decline from 46.0% in 1980 to 35.1% in 1989.<sup>8</sup> The impact of this loss of market share was vividly demonstrated on October 31, 1990 when GM announced a \$2.1 billion special charge against earnings to cover the cost of closing at least seven of its 38 assembly

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<sup>5</sup>S. C. Gwyne, "The Right Stuff," *Time*, October 29, 1990, p. 75.

<sup>6</sup>*GM Technical Staffs Communicator*, October 10, 1990.

<sup>7</sup>James P. Womack, Daniel T. Jones & Daniel Roos, *The Machine That Changed the World* (New York: Rawson Associates, 1990), p. 110.

<sup>8</sup>Michelle Krebs, "Once and Future King," *Auto Week*, July 30, 1990, p. 19.

**Table 2-1: Top-Selling Passenger Cars in the United States in Model Year 1990**

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<u>Model</u>	<u>Sales</u>
Honda Accord	417,000
Ford Taurus	317,000
Chevrolet Cavalier	288,000
Toyota Camry	278,000
Chevrolet Corsica / Beretta	278,000
Ford Escort	277,000
Honda Civic	255,000

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plants located in the United States and Canada.<sup>9</sup> Although GM has maintained its position as the largest vehicle manufacturer in the world, its historic formula for success has been severely shaken in the last decade. In the midst of such a competitive environment, GM must establish new keys to success in order to maintain its leading position in the coming years.

## THE ROLE OF INNOVATION

In *Industrial Renaissance*, William Abernathy, Kim Clark and Alan Kantrow state that:

...the circumstances in which the auto producers find themselves are characterized by increased competitive pressures from abroad that have, at their root, high levels of manufacturing performance and by a great ferment in product as well as process technology. For managers, this new and highly charged situation presents the formi-

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<sup>9</sup>Joseph B. White and Paul Ingrassia, "Smaller Giant: Huge GM Write-Off Positions Auto Maker to Show New Growth," *The Wall Street Journal*, November 1, 1990, p. A1.

dable challenge of regaining excellence in the management of production systems and technology, and - especially - both together.<sup>10</sup>

According to *The Machine That Changed the World*, over the past four decades the Japanese automakers have essentially redefined the process by which a car is designed and built. This process of *lean production* has introduced many innovations, among them just-in-time inventory systems, flexible manufacturing, total quality management, design for manufacturability, and simultaneous engineering. The end result is that, on average, Japanese producers can design a car faster and more efficiently, and then build it in a factory that boasts higher productivity than the domestic manufacturers. Lean production represents a powerful management technique that has been mastered by many Japanese automakers, and a portion of their success can be attributed to their ability to implement innovations based upon the inventions of others, such as their adoption of statistical process control techniques initially developed in the United States.

The ability to introduce new technology into the market quickly can be a particularly powerful competitive weapon. Womack, Jones, and Roos state that the powerful product

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<sup>10</sup>William J. Abernathy, Kim B. Clark, and Alan M. Kantrow, *Industrial Renaissance: Producing a Competitive Future for America* (New York: Basic Books, Inc., 1983), p. xi.



development capability of Japanese firms "has fundamentally changed the logic of competition in this industry. The producers in full command of these techniques can use the same development budget to offer a wider range of products or shorter model cycles - or they can spend the money they save by implementing an efficient development process for developing new technologies."<sup>11</sup> Since 1983, the Japanese motor vehicle industry has received more U.S. patents than American firms in spite of lower overall R & D spending.<sup>12</sup> More importantly, they are also quite effective at bringing these inventions to market. Infiniti recently ran a sixteen-page advertisement in the *Wall Street Journal* where it offered the following list of technical features in its product: multi-valve engines, speed-sensitive steering, anti-lock brakes, full-active suspension, 4-wheel steering, and an automatically adjusting steering wheel.<sup>13</sup>

Much of the traditional thinking regarding the impact of innovation within an industry relates to a model developed by Abernathy and Utterback, illustrated in Figure

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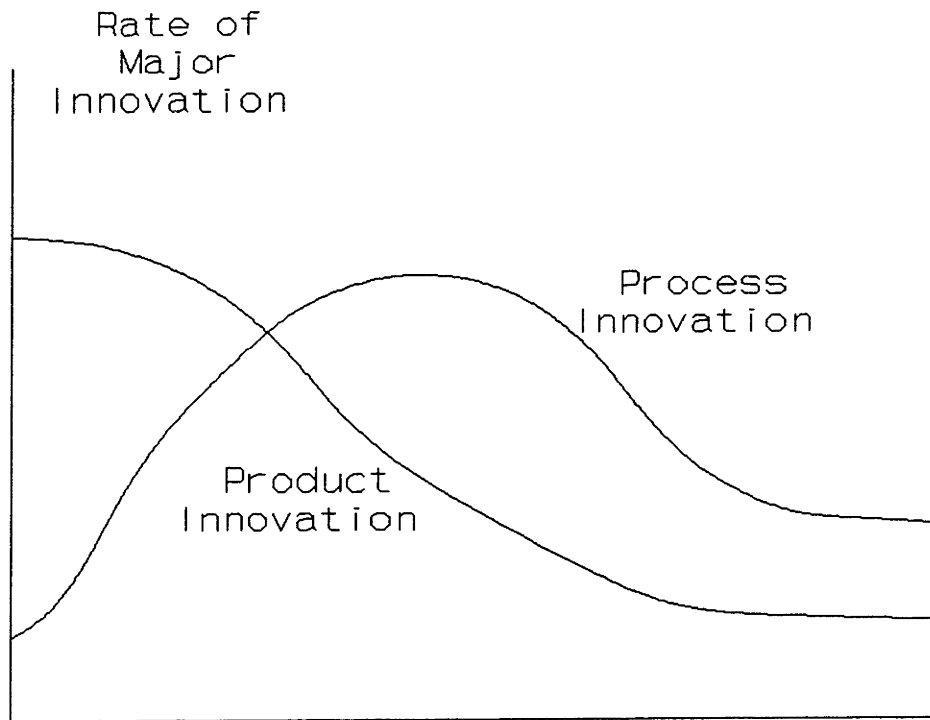
<sup>11</sup>Roos, Womack, and Jones, *op. cit.*, p. 127.

<sup>12</sup>*Ibid.*, pp. 133-134.

<sup>13</sup>*The Wall Street Journal*, December 6, 1990.

**Figure 2-1: A Model of Industrial Innovation**

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2-1.<sup>14</sup> This figure shows that as an industry matures, the emphasis changes from product innovation to process innovation. At the same time, incremental innovation becomes the dominant form of innovation, as opposed to radical innovation. This process of continuous improvement has proven to be a very effective means of obtaining performance and productivity gains. The cumulative impact

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<sup>14</sup>William J. Abernathy and James M. Utterback, "Patterns of Industrial Innovation," *Readings in the Management of Innovation*, ed. Michael L. Tushman and William L. Moore (Cambridge, Massachusetts: Ballinger Publishing Company, 1982), pp. 97-108.

of many small, incremental innovations on productivity and product performance can have a more pronounced effect over the long term than a few radical innovations.

Within this traditional framework, the impact of minor technical innovation is seen as positive from an industry perspective, but not as the basis for a competitive advantage. The line of reasoning is as follows:

... in mature industries minor technical changes are readily imitable. When new skills are embodied in equipment that is available for purchase by competitors, they do not easily become the foundation of long-lasting market ascendancy. For all intents and purposes, technically modest innovations in mature industries are relatively neutral in their effect on the terms of competition, if not on market success. When, however, we try to think of innovations that are likely to alter those terms, almost inevitably we think of ... radically new products and markets based on important scientific breakthroughs.<sup>15</sup>

In order to explain the tremendous impact that the process of continuous improvement has had on the competitive structure of the automotive industry, Abernathy, Clark and Kantrow introduce the concept of "de-maturity." They define a mature industry as one "in which an earlier uncertainty has been replaced by a stability in core concepts, a stability that permits process technology to be embodied in capital equipment or in engineering personnel and purchased in the marketplace."<sup>16</sup> The concept of de-maturity states

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<sup>15</sup>Abernathy, Clark, and Kantrow, *op. cit.*, p. 108.

<sup>16</sup>*Ibid.*, p. 24.

that the trend toward stability and maturity implicit in the traditional model can be reversed when there "is a major change in the established relationship between technology and market preferences."<sup>17</sup> They argue that such a change has occurred in the automobile industry, and that technology has become a prime competitive tool. Within a de-maturing industry, even minor technical change can have the disruptive capability normally associated with radical innovation. In the fifties and sixties, the industry had settled into a technologically dormant state. "In 1964, Donald Frey, vice-president of the Ford Motor Company, stated publicly that the last significant innovation in the auto industry was the automatic transmission, which went into production in the late 1930s."<sup>18</sup> Beginning in the mid to late seventies, the pace of technical innovation became significantly faster, and these innovations occurred in areas that impacted the traditional modes of doing business. Front-wheel drive, electronic engine and transmission controls, anti-lock brakes, fuel injection, and multi-valve engines are but a few of the innovations that have altered the basis of competition. By upsetting the traditional balance between established technology and the marketplace, these

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<sup>17</sup>*Ibid.*, p. 27.

<sup>18</sup>William J. Abernathy, *The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry* (Baltimore: Johns Hopkins University Press, 1978), p. 3.

new technologies have become significant competitive weapons, as much for the way that they impact the overall operations of the company as for their effect on the product itself. The role of innovation as a competitive force is summarized in *Industrial Renaissance*:

What is truly important about innovation, whatever its technical novelty, is the extent to which it changes an industry's basis of competition at the same time that it disrupts established production competence, marketing and distribution systems, capital equipment, organizational structures, and the skills of both managers and workers. In a mature industry, innovation is usually conservative, reinforcing the terms of competition. By contrast, in a de-maturing industry, even technically modest innovations can throw competitive logic and the nature of essential resources to the wind. Technology affects competition only to the extent that it - and the way that it - supports or threatens existing commitments: to production systems, to tactical plans and strategic goals, and to the use of resources.<sup>19</sup>

There are no signs that the current rate of technological change in the industry is going to abate. As the principles of lean production become more widely applied, the process of continuous improvement will slowly redefine the process by which cars are competitively produced. Advances in electronics, materials, and engineering methods promise additional refinements to the automobile as we know it today. However, more radical innovations in propulsion systems and vehicle architectures are certainly possible, as recent activity in electric vehicles has demonstrated.

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<sup>19</sup>*Ibid.*, p. 109.

Within this context, it is apparent that the ability to innovate will be essential for the successful automotive company competing in a global market. In an attempt to meet the competitive challenge of technological innovation, General Motors spent \$5.2 billion on R & D in 1989, more than any other U.S. company.<sup>20</sup> With such enormous sums of money involved, effective management of technological innovation, made possible by a better understanding of the innovation process, can be a powerful tool in the ongoing battle for market share and profitability.

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<sup>20</sup>Emily Smith and James B. Treece, "Glimpsing the Future in the Numbers," *Business Week*, 1990 *Innovation Issue*, p. 195.

## CHAPTER 3

### THE NATURE OF INNOVATION

As stated in the introduction, the largest concentration of R & D projects within GM can be found within the Technical Staffs. Within this group, there is a general feeling that more of these projects should result in new technology reaching end products and processes. This feeling is not unique to GM. A study of twelve major research laboratories in the U.S. "found that most large organizations ... were dissatisfied with the degree of transfer of their own R & D results. They felt uncomfortable about how little of their good technical outcomes ever reached the marketplace and generated profitable payback for the firm."<sup>21</sup> Given this apparent shortfall in innovative performance, an understanding of the issues that influence the adoption of new technology into a vehicle should provide some insight into ways of increasing the number of projects that are successfully transferred from various R & D activities to the operating groups. This chapter will identify major characteristics of the innovation process, quantifiable parameters common to automotive projects, and some process and organizational issues that have been shown

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<sup>21</sup>Edward B. Roberts, "Stimulating Technological Innovation - Organizational Approaches," *Research Management*, November, 1979, p. 29.

to enhance the innovation process. The questions contained in the surveys that were distributed for this thesis were focused upon these three areas.

## **CHARACTERISTICS OF INNOVATION**

In order to more thoroughly understand the issues affecting successful technological innovation, it is important to understand some of the key characteristics of the innovation process that make it difficult to manage. These characteristics include: the dual requirements for innovation, the relationship between innovation and science, the destructive capability of innovation, and the conflict between productivity and innovation. The following sections will define these characteristics and their impact on the innovation process.

### **Dual Requirements for Innovation**

A frequent topic of discussion is whether technical innovation comes from "technology push" or "market pull." Although the initial impetus for innovation can be in either a technological discovery or a perceived market need, both must eventually be present to result in a success. Based upon a study of 567 innovations, Marquis states that "suc-



cessful innovation begins with a new idea which involves the recognition of both technical feasibility and demand."<sup>22</sup>

Of the innovations that Marquis studied, 75% were initiated by either a market demand or a production need. This leads him to state that "recognition of demand is a more frequent factor in successful innovation than recognition of technical potential."<sup>23</sup> These findings should have significant impact upon the structure and communication patterns present in industrial R & D organizations. My experience is that R & D organizations, comprised of highly capable technical people, are inclined to pursue technologies based upon their capabilities and interests without sufficient understanding of market and manufacturing issues. Every effort should be made to assure that market, sales, and manufacturing information reaches the core of the R & D group, and that this information is fully utilized in the selection and objectives of development projects.

A caveat regarding the role of technology development is appropriate here. Mowery and Rosenberg have pointed out that many of the empirical studies documenting the "dominance" of market pull on successful innovation have some

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<sup>22</sup>Donald G. Marquis, "The Anatomy of Successful Innovations," *Readings in the Management of Innovation*, ed. Michael L. Tushman and William L. Moore (Cambridge, Massachusetts: Ballinger Publishing Company, 1982), p. 44, (emphasis in original).

<sup>23</sup>*Ibid.*, p. 47.

disturbing flaws.<sup>24</sup> There are certainly examples of successful innovations that have been developed without the obvious presence of a market need. These examples tend to be radical in nature, such as the digital computer, the personal computer, and the Sony Walkman. Since both a market need and the technological wherewithal to meet that need are both required for success, it would be inappropriate to suggest that R & D agendas should be set solely from marketing surveys. However, attuning the R & D organizations to general market characteristics is a strategy that is highly unlikely to lead to misdirected effort.

#### **Innovation and Science**

Many people hold the view that the key to innovation is strong basic science. In fact, there is little evidence to support this concept. According to Rustum Roy, the director of Science, Technology, and Space Programs at Pennsylvania State University, "the idea that fundamental science generates technology is 'grossly erroneous.' Usually, technology pushes science."<sup>25</sup> Allen states that "it is becoming generally accepted that technology builds upon itself and

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<sup>24</sup>David C. Mowery and Nathan Rosenberg, "The influence of market demand upon innovation: a critical review of some recent empirical studies," *Research Policy*, Vol. 8, April, 1979.

<sup>25</sup>Otis Port, "Why The U.S. Is Losing Its Lead," *Business Week*, 1990 *Innovation Issue*, p. 38.

advances quite independently of any link with the scientific frontier, and often without any necessity for an understanding of the basic science which underlies it."<sup>26</sup> Finally, Utterback points out that where technology is based upon a scientific discovery, "there is a substantial time lag, 8 to 15 years, between the time technical information is generated and the time it is used in an innovation."<sup>27</sup>

Given the apparent decoupling between basic science and innovation, what are the implications for organizations which desire to improve their innovative performance? The concept that information is "out there" waiting to be harvested into an innovation can hardly be accurate - in many cases the puzzle of innovation can only be solved when all of the pieces are developed and known. However, as the previous section pointed out, a successful innovation requires a match between a technology and a market need. The fundamental problem once again appears to be related to the ability to gather and process both technical and market information, and provide an environment where people can recognize the opportunities latent within these streams of information.

The above statements are not meant to imply that basic research is not important. It plays a significant role in

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<sup>26</sup>Thomas J. Allen, *Managing the Flow of Technology* (Cambridge, Massachusetts: The MIT Press, 1977), p. 48.

<sup>27</sup>James M. Utterback, *op. cit.*, p. 622.

the orderly advance of scientific knowledge, and through the educational system, provides a basis for innovative developments over the long term. These issues form a strong argument for the foundation of basic research to be based upon university and government efforts. Strong commercial R & D organizations should: 1) track the progress in basic science over the long haul, 2) understand the explicit and latent technological needs of the company and marketplace, and 3) utilize technical resources to develop and understand those technologies that provide the firm with a competitive advantage. Although somewhat industry specific, the role of company-sponsored basic research will generally be relatively small.

### **Destructive Capability**

Most of us have a tendency to look at innovation, in hindsight, as a tremendously positive force for change in our society. We see the benefits of personal computers, microwave ovens, and cellular telephones and tend to forget the destructive force that accompanies innovation. In fact, it is difficult to achieve progress without tearing down some of the old order, just as an old building must be razed to make way for a new skyscraper. The double-edged sword of innovation causes it to be resisted in many instances.

The destructive nature of innovation seems to be most visible in the large, established firm. Quinn points out

that since any innovation contains some degree of risk, large companies may not be amenable to "jeopardizing the many other products, projects, jobs, and communities the company supports. Even if its innovation is successful, a big company may face costs that newcomers do not bear, like converting existing operations and customer bases to the new solution."<sup>28</sup> An innovation which threatens a firm's own large and profitable existing business will face detractors from the many vested interests in the old technology or systems. An excellent example of a firm resisting innovation until it was nearly too late is the case of National Cash Register, which in 1971 took a \$140 million charge to write off newly designed electromechanical cash registers which were rendered obsolete by newer electronic machines. Thousands of workers were laid off, the CEO was fired, and the stock price plummeted.<sup>29</sup> An important lesson is that although innovation may be resisted within the confines of an individual company, it is rarely kept at bay indefinitely in the competitive marketplace. For firms which desire to remain going concerns, "the implementation of innovations often results in eliminations, replacements, or transformations of existing arrangements. As a consequence, the management of innovation must also be the management of

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<sup>28</sup>James Brian Quinn, "Managing Innovation: Controlled Chaos," *Harvard Business Review*, May-June, 1985, p. 73.

<sup>29</sup>Richard N. Foster, *op. cit.*, pp. 27-28.

termination, and of transitioning people, programs, and investments from commitments in the past toward the future."<sup>30</sup>

This side of managing innovation often receives too little attention. Manufacturing workers can be expected to resist new technology intended to improve productivity when their jobs may be placed at risk by that technology. Knowledge workers can see their positions of status and authority undermined by innovations that lessen the value of their expertise and experience. Large investments in systems, equipment, and relationships may be put at risk. Any firm which seriously desires to be an effective innovator must learn to deal with these types of issues in order to allow innovative ideas to receive their proper attention and consideration.

### **Innovation and Productivity**

Joseph Schumpeter called technological change a "'gale of creative destruction,' wrecking industrial lethargy and leading to improvements in productivity for the benefit of society."<sup>31</sup> A look back at the automotive industry shows many innovations that have led to increased productivity,

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<sup>30</sup>Andrew H. Van de Ven, "Central Problems in the Management of Innovation," *Readings in the Management of Innovation, 2d Edition*, ed. Michael L. Tushman and William L. Moore (New York: Ballinger Publishing Company, 1988), pp. 114-115.

<sup>31</sup>William J. Abernathy, *op. cit.*, p. 3.

among them the use of interchangeable parts, the moving assembly line, and automation. Yet, in what William Abernathy defines as the "productivity dilemma," the widespread use of each of these techniques somewhat reduced the capability of the industry to innovate further. "Stated generally, to achieve gains in productivity, there must be attendant losses in innovative capability; or, conversely, the conditions needed for rapid innovative change are much different from those that support high levels of production efficiency."<sup>32</sup>

This focus on productivity and process refinement, although quite desirable and necessary, gradually causes the firm to become "locked" into a specific form of the product due to the investment and specialization that have taken place to obtain the desired progress. As an industry progresses along the path of incremental innovation, firms typically reduce their capability to process and respond to external information. Therefore, they become more susceptible to being overtaken by a substantial innovation from outside the industry.

Automotive managers of technology therefore face a dilemma. The automobile, as a consumer durable, is a product which faces substantial cost sensitivity. However, a continued drive to focus an entire corporation on cost

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<sup>32</sup>*Ibid.*, p. 4.

reduction contains the hazard of reducing the capability of the organization to innovate. There are very few mechanisms for resolving this dilemma. The most common approach has been to introduce a technological innovation into the luxury segment of the market, where price sensitivity is somewhat lower. As experience provides the ability to reduce cost, the technology is introduced in the broader segments of the market. Absent any specific recommendations, an awareness of the conflicting requirements for innovation and productivity provides the technological manager with an important view of the types of innovation most likely to be accepted within the firm.

## **QUANTIFIABLE DEVELOPMENT ISSUES**

The quantifiable issues of a development program typically receive the most attention from the R & D staff. These issues are typically captured in various specifications and business plans, and a great deal of effort is expended to generate and comply with these requirements. From an engineering perspective, the development process can be viewed as the sequence of steps taken to reduce the level of uncertainty present in each quantifiable issue. When the requirements relating to each issue have been satisfactorily developed to within an acceptable level of uncertainty, then a decision whether or not to proceed with a production program can be made. These quantitative issues include



technical performance, market forecasts, quality and reliability, cost, capital requirements, and program timing.

### **Technical Performance**

The essence of a technological innovation is captured in its technical performance. A new technology is usually attractive because of the new or improved aspects it brings to the vehicle. Consequently, a great deal of effort is expended to understand and refine the performance of the technology. This is often a process that can take several years and consume significant resources. The quantification of technical performance involves significant design, prototyping, testing, and redesign. Eventually, a specification begins to take shape which is generally a compromise between what is desired and what seems possible to achieve. If the invention is "technology driven," the involvement of appropriate operating groups will be sought when it appears that there is adequate potential and a demonstration can be made.

### **Market Forecasts**

Market forecasting for new technology is an extremely difficult task. This is especially true in the automotive industry, where product development is a process spanning several years. In order to get an estimate of market demand for a new technology, consumers must be familiarized with the technology and its benefits and then questioned as to

their possible purchase intent. Given that the technology will not be made available for three or more years, the market forecast thus achieved is highly uncertain.

This uncertainty in forecasting market acceptance works against most new technologies. The costs associated with developing the technology are quite high, and if sales fall below expectations, losses will probably be incurred. Most decisions are taken from a highly conservative viewpoint in that the marketing survey must indicate a very high level of interest before a production commitment will be made. Additionally, there is no attempt made to attribute "plus sales" to a new technology. This means that the new feature is evaluated on the basis of its profit margin in the considered models, without considering whether the presence of the technology will result in more sales of the model than would occur if it were not available. Among significant innovations, only those that have a very high perceived probability of success are able to meet the above requirements, unless the technology appears in a competitive vehicle, but at that point the organization can no longer be considered the innovator.

### **Quality and Reliability**

Quality and reliability have become extremely important issues in the automotive industry. In order to introduce a new technology, the impact on the overall quality and

reliability of the vehicle must be established. In the case where the technology introduces a new feature or option with additional hardware, it is very difficult to implement a new system that will not introduce some additional failure mechanisms in the vehicle. This fact can be used to reject a technology that may be desirable, even when it can be shown that as a separate system, its quality and reliability are quite good. Managers responsible for developing a vehicle have rigorous overall quality goals to meet, and they are not necessarily amenable to adding items that will make those goals more difficult to attain.

### **Cost**

Cost has long been the prime driving force in the automotive industry. The cost of new technology is always carefully estimated prior to implementation, and these cost estimates soon become regarded as fact. In actuality, as any accountant will testify, there is considerable leeway in any cost estimating procedure. Most of this leeway comes in the form of allocated costs such as depreciation and overhead. Within GM, the responsibility for cost estimating falls with the appropriate operating group. If they are opposed to the new technology for some reason, the cost estimating function is a convenient place to construct a barrier. This occurs outside of GM as well, for Roberts states that "corporate R & D organizations were dependent on

product line divisions for both marketing and sales efforts, and for business and economic analysis as well. The latter dependency was particularly harmful in getting the projects being done in R & D justified and supported by the divisions who were supposed to be the eventual customers of technical results."<sup>33</sup>

### **Capital Requirements**

Another significant factor impacting the introduction of new technology is the requirement for investment capital. Outlays for new facilities and tooling are usually required for significant innovations. The financial and business analysis must not only include the unit costs discussed above, but also the capital requirements. This approval process can serve as yet another hurdle in the innovation process.

### **Program Timing**

A popular phrase states that "timing is everything." Although that may not be entirely true in the introduction of new technology, timing is of critical importance, particularly when the technology is fundamental to the operation of the vehicle. In that case, a delay in the development of the new technology will cause the entire

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<sup>33</sup>Edward B. Roberts, *op. cit.*, p. 29.

vehicle program to be delayed, at a tremendous cost in lost sales and unused facilities. Operating managers are in an environment where their success is judged on their ability to bring product out on time, within budget, and with acceptable quality. A new technology which introduces uncertainty in any of these areas will likely be somewhat unwelcome.

Major changes to a particular vehicle model are usually made on a periodic basis of no less than four years, and often longer. If a certain technology widely affects the vehicle configuration, the opportunity for the technology to be considered for that vehicle occurs within a relatively short time frame prior to the overall concept approval of the vehicle. If this "window of opportunity" is missed, the next opportunity for introduction of the technology may be several years away. Therefore, a new technology under consideration must be sufficiently developed for the vehicle program to evaluate the technology at the outset of the vehicle program so that the managers can include the new technology in their product and process development planning.

## **PROCESS ISSUES**

As the preceding discussion has revealed, the characteristics of the innovation process make it difficult to manage, and the quantifiable issues are often subject to

varying degrees of manipulation and interpretation depending upon the orientation of the various groups and individuals. A final perspective is to examine how certain aspects of the innovation process may be managed in an attempt to overcome the various difficulties that have been mentioned. Three approaches will be examined: staffing of critical functions, the use of multi-functional teams, and the use of bridging mechanisms between organizations.

### **Critical Functions**

Roberts and Fusfeld have identified five critical functions which are generally required in order for a successful innovation to take place. These functions are defined as:<sup>34</sup>

- Idea Generating - The process of analyzing and synthesizing information from a variety of sources into an idea for a new invention, product, or service.
- Entrepreneurship or Championing - The process of recognizing, proposing, demonstrating and pushing the new idea through the organization to obtain formal approval.
- Project Leading - The organizing and planning of the various activities required to implement the concept.
- Gatekeeping - Collecting information from outside the organization and channeling it to the appropriate people within the organization. The

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<sup>34</sup>Edward B. Roberts and Alan R. Fusfeld, "Staffing the Innovative Technology-Based Organization," *Readings in the Management of Innovation, 2d Edition*, op. cit., pp. 313-314.

information may be related to technologies, markets, or manufacturing.

- Sponsoring or Coaching - The process of guiding and developing less experienced team members, protecting the project from its detractors, and providing general status to the project.

One reason why the fulfillment of these critical roles helps improve the chance of success relates to the way in which uncertainty is resolved. All projects will encounter unexpected problems and difficulties throughout the development period, but successful projects find ways to overcome these difficulties. Each critical function, either directly or through the obtaining of appropriate resources, helps overcome or prevent obstacles which could endanger the project. By showing continued progress, the project gradually obtains higher levels of commitment from the organization.

### **Multi-Functional Teams**

Another factor often attributed to successful technical projects is the formation of multi-functional teams. Given the multi-disciplinary nature of many products today, the inclusion of each discipline early in the design cycle prevents the redesign and loss of information that has historically occurred as designs progress through R & D, Marketing, Finance, and Manufacturing. Not only does this result in a product which addresses the needs and concerns of each group, but by involving each area beyond R & D early in the design process, there is a "much greater assurance that those other functions are going to be in accepting and

supporting moods when the time comes for them to be pushing forward the product idea."<sup>35</sup>

### **Bridging Mechanisms**

A final approach to addressing the problem of technology transfer is to build "bridges" between the different organizations downstream of the R & D group.<sup>36</sup> In a variety of ways, these bridges attempt to overcome barriers by making the transfer of information between organizations more complete and less burdensome. Approaches such as joint planning and staffing of R & D projects are examples of procedural bridges. Human bridges focus on transferring information through the movement of people on either a temporary or long-term basis. Finally, organizational bridges include such approaches as liaison managers and venture teams. Each of these techniques can be successful in the proper environment, given a sufficient degree of management attention and support.

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<sup>35</sup>Edward B. Roberts, *op. cit.*, p. 28.

<sup>36</sup>*Ibid.*, pp. 29-30.



## CHAPTER 4

### RESEARCH METHODS

At this point, it is clear that the decision to incorporate new technology into an automobile is influenced by a wide variety of factors. To obtain some first-hand data on how the process actually occurs within GM, seven advanced development projects were identified as appropriate candidates for in-depth study. In order to be selected for inclusion in the study, a project had to have several characteristics. Most importantly, projects were selected that had demonstrated technical success at the prototype level. The risk of technical failure is certainly an important consideration in R & D activities, but it was not the focus of this study. Secondly, selected projects had pursued inclusion in specific production-intent programs, i.e., they had a targeted vehicle and model year for their first intended application. Finally, it was required that a decision had been reached on whether or not to include the technology in the specific production application. This allowed the projects to be segregated into two groups: projects classified as successful were selected for use by the targeted vehicle programs, projects deemed unsuccessful were not.

It is important to note that the terms "successful" and "unsuccessful" are in no way intended to reflect upon the quality of the efforts of the project team. As stated above, each project within the sample was selected because technical issues had been resolved to a great extent. Successful technological innovation is a complex process involving a great number of variables, many of which are extremely difficult to control. Since this thesis is focused upon the issues affecting the decision to actually apply new technology in a production vehicle, the result of this decision represents an objective measure of project success.

Each project selected for inclusion in the study originated in one of the corporation's advanced development activities. The projects involved several different corporate groups, including staffs, vehicle groups, component divisions, and in some cases, outside suppliers. The projects selected were as follows:

- Component Systems:
  - Antilock Brake System VI (ABS-VI)
  - Head-Up Display
  - Slot Antenna
- Process Innovations:
  - Hydroformed Roof Rails
  - Multibent Headers
  - Single-Sided Spot Welding

- Vehicle Project
  - Chev-200 Low Cost Vehicle

Table 4-1 tabulates some basic attributes of each of the projects. Chapter 5 gives an overview of each project and its history.

**Table 4-1: Surveyed Projects and Success Status**

<u>Project</u>	<u>Vehicle Target</u>	<u>Success</u>
ABS-VI	N Platform, Saturn	Yes
Head-Up Display	W Platform	Yes
Slot Antenna	GM-350	No*
Hydroformed Roof Rails	Confidential	No*
Multibent Headers	Confidential	Yes
Single-Sided Spot Welding	Confidential	No*
Chev-200	Chev-200	No

\*Other applications achieved or planned in spite of failure to meet initial target application.

A written survey consisting of 22 questions was generated using the information presented in Chapters 2 and 3. Appendix A contains a copy of the survey. This survey was distributed to all individuals who were reported to have been participants in the various projects. The survey was accompanied by a cover letter explaining its purpose, along with a postage-paid, self-addressed envelope for its return. The cover letter stated that individual responses would be kept confidential, although individual identification was optionally requested.

Whenever possible a personal or telephone contact was made to encourage each individual to participate. Follow-up calls were made via a voice-mail system to groups that initially showed low response rates. These steps were taken in order to obtain a high rate of response, which was necessary due to the limited number of surveys that were distributed.

The data were analyzed by calculating the difference between the mean responses on each question for successful and unsuccessful projects. Those questions that strongly differentiated between successful and unsuccessful projects were identified and analyzed. The same procedure was repeated after sorting the responses between staff and operating group personnel in order to identify differences in perceptions between these two groups. Detailed results of the analysis are given in Chapter 6.

## CHAPTER 5

### PROJECT DESCRIPTIONS

In order to obtain a more thorough understanding of the projects that were included in the study, personal and telephone interviews were held with key individuals who had been involved with each project. The following sections contain information obtained from those interviews relating to the history, motivation, and success of each of the projects.

#### COMPONENT SYSTEMS

Component systems represent a subsystem of the vehicle that can be regarded as generic technology specifically adapted to a vehicle platform. In the case of the three systems discussed below, the original work on the system was done in a development environment, then particular production applications were pursued after the technology had been initially demonstrated.

#### ABS-VI

The concept of antilock braking systems in vehicles has been around for several decades. In fact, General Motors had experience in incorporating these systems in heavy trucks in the seventies as a result of legislation requiring

their use. Reliability problems resulting from the immaturity of the technology resulted in withdrawal of the legislation, and GM abandoned virtually all development efforts on such systems.

In the early eighties, interest began to reemerge in installing ABS in production vehicles. Two German companies, Bosch and Teves, had developed systems which were being marketed to vehicle manufacturers worldwide. By the mid-eighties, GM was offering systems from these manufacturers on several models.

Traditionally, antilock systems consist of four major components: wheel speed sensors to detect wheel lock, electromechanical solenoids capable of modulating the brake fluid pressure at each wheel, a pump enabling brake pressure to be maintained once the system has been activated, and an electronic control unit designed to implement the antilock algorithms. Because of their complexity, traditional systems are expensive, and are therefore limited in their application to relatively upscale vehicles.

In the early eighties, a group at the Research Laboratories (GMR) began working on electric power steering systems. These systems utilized electric motors instead of hydraulics to provide the steering assist. A combination of suggestions from operating groups and the needs of an electric vehicle program led the group to investigate a full brake-by-wire system that utilized motor-driven pistons to

control the braking force. Delco Moraine, the corporation's component division responsible for braking systems, was contacted regarding the system in late 1983.

Following input from various operating divisions, the group simplified the system from a full brake-by-wire system to a system designed to implement only the antilock function. At this point, the group began to realize that because the system could be "added on" to a conventional braking system without additional pumps and complex plumbing, there was substantial potential for a lower cost antilock system. This effort eventually developed into the ABS-VI project.

At the same time, Delco Moraine had initiated a program to develop its own antilock system called Powermaster III. The Powermaster III program was a traditional system that pursued incremental performance and cost advantages over systems from the outside suppliers, and was successfully put into production in model year 1988. It is felt that the Powermaster III program was an important stepping stone to ABS-VI in that it allowed Delco Moraine to develop expertise in antilock systems and establish itself as a bona-fide supplier of such systems with the corporation's vehicle groups.

As it became obvious that there was growing interest in ABS throughout the vehicle groups, GMR stepped up efforts to raise interest in its low cost system. A sense of urgency

developed due to the impression that a finite window of opportunity existed. Once a particular vehicle platform made a decision to include a specific system, there would be a tremendous amount of inertia to overcome in order to replace that system with a new one. Eventually, groups from the N-car (Pontiac Grand Am, Oldsmobile Cutlass Calais, and Buick Skylark) and Saturn expressed a desire to develop the system for production applications. This encouraged Delco Moraine to become more fully involved in the project.

Several other issues relating to the successful development of the project are worth mentioning. The clear motivation for the project from early in the program was to implement a system that was substantially less expensive to build than traditional systems. Because other efforts, in particular the Powermaster III, were predominantly focused on performance improvement, a shift in perspective was required. It was eventually recognized that the ABS-VI system could provide nearly all of the performance of traditional systems, yet could be made much more widely available due to its substantially lower cost.

Another factor related to the success of ABS-VI is the involvement of certain key individuals. At both staff and divisional locations, certain people were cited as playing a key role in maintaining interest and support for the project. The point was stressed that in the early days of the project, one manager could rely upon contacts within the



corporation that were more influential than his position would have suggested, and that this was critical to the success of the program.

By all accounts, the ABS-VI project represents a highly successful effort involving the entire spectrum of corporate engineering organizations. It was introduced, as scheduled, in the 1991 N platform, and will be offered on many other GM car lines, including Saturn, in the near future. One measure of its success was that *Popular Science* named ABS-VI as the automotive technology grand award winner in the magazine's "Best of What's New" issue in December, 1990.<sup>37</sup>

### **Head-Up Display**

Head-up displays (HUDs), where important information is projected on the windshield of the vehicle, have been used in military aircraft for many years. By using optical systems that project information into the driver's forward field of vision, the need for the driver to divert attention from the road and refocus his eyes on the instrument panel is significantly reduced. Basically, a HUD system consists of a specially designed display, interface electronics, projection optics, and a reflective windshield. Displayed information, such as vehicle speed, appears to float in space above the front bumper of the vehicle.

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<sup>37</sup>"3rd Annual Best of What's New," *Popular Science*, December, 1990, p. 74.

Following the acquisition of Hughes Aircraft in 1985, there was a great deal of interest in identifying technologies from Hughes that could be applied in the automotive side of the business. Early on, the HUD became a strong candidate for such a technology. Several vehicles from CPC's Advanced Vehicle Engineering (AVE) group were sent to Hughes for concept installations, and by the summer of 1987, AVE was actively seeking a production commitment from various platform groups. A key goal of AVE was to seize a marketing advantage for GM, Delco Electronics, and Hughes by being first to market with an automotive HUD.

As efforts continued to find a market application for the technology, it was generally recognized that normal lead times would not allow production introduction until 1991 or 1992. AVE began to propose a "presence program" that would aggressively develop the technology for earlier introduction in a low volume application. Until October of 1987, little progress was made in this direction.

In mid-October, Nissan announced that it had developed a HUD for automotive use. The possibility of being upstaged in HUD technology by a competitor galvanized the engineering and marketing organizations of the company. Within approximately 3 months, decisions had been made to introduce the HUD in two "fast-track" programs, the 1988 1/2 Oldsmobile Cutlass Supreme Indy Pace Car and the 1989 1/2 Pontiac Grand Prix Turbo.

As a result of these decisions, GM introduced the HUD to the market almost simultaneously with Nissan. Several factors are attributed to the success of the project. Several management level champions were involved in sponsoring the project and its goal of being first to market. Secondly, the Oldsmobile program involved a limited number of vehicles that were modified by an outside contractor. Finally, the project was never passed to the normal production groups. AVE kept management responsibility for the project, and worked directly with Delco Electronics and Hughes engineers in a small design team. HUDs are still available in the W platform (Oldsmobile Cutlass Supreme and Pontiac Grand Prix), and additional applications are planned in the future.

### **Slot Antenna**

For many years, there has been dissatisfaction in the automotive engineering community with mast radio antennas. This is due to a variety of reasons, including styling, wind noise, fuel efficiency, and maintenance. For a substantial period of time beginning in the early seventies, GM embedded radio antennas in the windshield of the automobile. By 1988, this approach had been completely abandoned, predominantly because of poor reception performance. The slot antenna project was first initiated at the Research Labs in 1976 as an alternative to fixed mast and power mast antennas.

A slot antenna is a small aperture, or opening, in a conductive sheet. The characteristics of the antenna are determined by the geometry of the sheet and the aperture. In an automotive application, it is desired that the conductive sheet be parallel to the ground, and that it not be shielded by any other metallic surface. In practice, this necessitates a plastic panel to be used for either the roof or rear deck lid of the vehicle. The antenna can then be manufactured by spraying a conductive material or mounting a foil sheet to the underside of the surface.

GMR's initial activity in slot antennas lasted for about one year. In the early eighties, a request was received from a group at Advanced Engineering Staff to develop an antenna for an experimental composite vehicle, and the project was resurrected. As understanding of the technology grew, interest was expressed by a limousine project which was planning to stretch a Cadillac sedan. The slot antenna would have been part of a composite roof section in the expanded portion of the vehicle. However, the limousine program was canceled prior to the introduction of the antenna.

The next program to consider the slot antenna was the APV program (Lumina APV, Pontiac Trans Sport, and Oldsmobile Silhouette). This vehicle, composed of a metallic frame with plastic body panels, represented an attractive application. However, as the final production content decisions

were made, it was decided that there was substantial technological risk already incorporated in the APV, and that the application of the slot antenna to the vehicle should be postponed.

The program that was surveyed for this thesis involved developing the slot antenna for the 1992 GM-350 (Buick Roadmaster) program. This vehicle was slated to use a plastic rear deck lid, and there was a general feeling that the slot antenna would only be an incremental complication. Individuals from GMR, AES, CEMSS, and CPC were assigned to help implement the system for production. However, the antenna once again was sidelined when the plastic rear deck lid was dropped due to manufacturing concerns regarding plastic and metal panels on the same vehicle. The desire to have a slot antenna was evidently not great enough to force these manufacturing issues to be resolved in another way.

As this chronology indicates, the slot antenna has had several near misses at a production application in the last five years. Yet, in each instance, one issue or another became a "show stopper" before the production release occurred. It therefore represents the first example of an unsuccessful project for the purposes of this investigation.<sup>38</sup>

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<sup>38</sup>As is often the case, a successful application was eventually developed. The slot antenna is currently scheduled to be released in the 1992 APV.

## **PROCESS INNOVATIONS**

The following three projects were initiated in an Advanced Engineering Staff program called Flexible Architecture Structure Technology (FAST), and are thus somewhat related. The goal of the FAST program is to integrate design and manufacturing technology to achieve more economical variation in product through approaches that require lower investment. The results of these efforts are fully developed design concepts that must encompass issues such as structural requirements, crashworthiness, packaging, and assembly. The three projects that were surveyed were each considered for use in the same vehicle program, and all represent technologies that continue to receive ongoing effort.

### **Hydroformed Roof Rails**

The roof rail is a structural component of the vehicle that forms the side supports for the roof. This arch-shaped component is typically manufactured from seven or eight stampings that are welded together. A single stamping can require a die for each step in the stamping process, resulting in very high investment for dies. Since this component forms the basic roofline for the vehicle, there is a desire to provide the capability to reduce the investment required for it in order to make frequent styling changes more economically feasible.

Another difficulty associated with making the roof rail from a set of stampings is the amount of waste generated. Each stamping must be formed from flat stock, and additional material is required to retain the part in the die. The amount of material that is eventually removed as scrap can approach fifty percent of the initial stock.

Hydroforming is a process by which structural frame members with closed cross-sections are formed from tubes. The tubing is manufactured or purchased in the required length, then bent to allow it to be inserted into a die. The tube is loaded into the die and the ends are sealed. The tube is then filled with fluid, the die is closed, and the pressure of the fluid is then increased. This pressure expands the tube from the inside, causing it to conform to the shape of the die. In this manner, the component can be fabricated using one set of dies rather than the eight or so sets required for a conventional stamping. The welding process required to join the two halves of a conventional stamped component is also eliminated.

In addition to the investment and process benefits outlined above, hydroforming has two additional benefits. Because the component is manufactured from a single piece of material, it has greater structural integrity than a conventional stamped component. Also, the amount of waste generated in the hydroforming process is nearly an order of

magnitude less than in a conventional process, resulting in significant material savings.

Although hydroforming was considered for the vehicle program mentioned above, it was not selected. Two reasons are stated for this decision. First, the perceived level of risk associated with the project was too high. If the hydroforming process did not work, the impact to go back and rework a conventional roof rail would have been very difficult in a compressed time schedule. Secondly, a late styling change in the program required the roof rail to be exposed rather than concealed under the roof panel. This required that the roof rail have a surface suitable for an exterior finish, and not enough work had been done at the time the decision was made to determine if this was possible.

This case represents the second project classified as unsuccessful for the purposes of this study. However, as was the case in the slot antenna project, there have been very positive results from the project apart from its initial goals. Although hydroforming was not selected for the roof rails, the same vehicle program did select the process for other structural components not initially considered by the FAST program. The FAST program initially concentrated its efforts on components that were highly styling-driven. However, the benefits of reduced investment and scrap are beneficial for components that do not fall



into this category. This represents an excellent example of the cross-fertilization that can occur when a broader group of people become familiar with a new technology.

### **Multibent Headers**

Headers are structural components that are located above openings for glass. Headers therefore exist for doors, windshields, and backlights. The main emphasis of the multibent headers project was to pursue an alternative process for forming windshield and backlight headers.

Once again, the conventional process for forming a header is to weld two hat-shaped stampings together to form a closed section component. Multibending is a process that combines roll forming with a numerically-controlled bending process to allow complex curves or sweeps to be constructed with very little investment in design-specific tooling.

Roll forming is a high-volume fabrication process in which the desired shape is formed as flat strip stock is progressively fed through a series of matched contoured rolls. As the material passes over each successive set of rotating dies, it comes closer and closer to its final shape. In the case of a closed section, the part may be welded as it exits the roll former. In the past, if any curves or sweeps were required for the constant cross-section part, they were limited to relatively simple constant radius sweeps.

The multibending process is designed to take place as the part exits the roll former. The multibender is essentially a multi-axis numerically-controlled machine that the header is forced through. As the header is fed into the machine, the required rotation and translation movements are executed to bend the part into the desired configuration. The result is that a virtually completed header can be manufactured in one continuous process with a minimum of design-specific tooling.

Multibending provides many of the same advantages that hydroforming exhibits, including lower material scrap. In addition, parts that are required to have mirror images for left and right side usage do not require separate tooling. The program for the multibender is simply modified to create either desired part. Since the cross-sections are the same, no hard tooling needs to be changed.

The multibending process has been used in the past on relatively light trim pieces, but it has never been applied to major structural components. The vehicle program has committed to using multibending for its windshield headers, and will also apply it for several other structural components. The multibender itself is being constructed at AES, and will be installed at an Inland-Fisher Guide facility for production operation.

### **Single-Sided Spot Welding**

The single-sided spot welding project was a direct result of the hydroforming and multibending projects. Conventional spot welding is done with two electrodes, one on each side of the weld area. The current flows between the two electrodes, forming the weld. When body structure components are made conventionally, it is common practice to punch access holes for spot welding equipment in the course of forming the stampings. However, when closed-section members are fabricated using the advanced processes previously described, it is undesirable to add process steps to make these openings. The structural integrity of closed-section parts is an attractive design feature, and any access holes reduce the components' structural strength. Single-sided spot welding was developed so that only one electrode tip is required to be at the weld location, while the other electrode is a back-up that serves to provide stability to the welded piece and a return path for the weld current.

A primary benefit of the single-sided spot welding process is that conventional welding equipment can be utilized. The only modifications that are required relate to the shape and positioning of the electrodes. Although several constraints to the use of the process exist, the most significant are that the back piece must be thicker

than the front piece, which cannot be made of galvanized steel.

Although successful production trials for single-sided spot welding have been performed, the technology was not included in the targeted vehicle program. The primary reason given was that a styling change was made that made another joining approach other than welding attractive. Although not included in this particular program, it is felt that other applications will be found in the future.

## **CHEV-200**

The last project that was included in the investigation differed from the others in that it was an entire vehicle project. By their very nature, vehicle projects involve more complexity in the engineering and decision process than do more specific projects. However, the Chev-200 project provides an interesting study in some of the aspects of a vehicle program that can lead to difficulties.

The basic goal of the Chev-200 project was to develop an extremely low cost vehicle that would appeal to the entry market. Aggressive targets for corporate variable cost and investment were set, and the project went through several iterations before finally being canceled in 1987. The project started in the CPC organization, but was transferred to AES in 1986. Over the course of the project several different vehicle concepts were developed.

One approach that was taken within the project was to approach systems from the perspective of understanding cost drivers, i. e., those aspects of the system design that most strongly influence cost. Once the cost drivers were identified, a "clean sheet approach" was to be used to develop low cost systems. A global sourcing strategy was to be used to find the lowest cost components and systems on a worldwide basis.

Several comments were made during the course of interviews that give some view of why the project experienced difficulties. Although the project had high-level corporate sponsors, the Chevrolet marketing organization was evidently not enthusiastic about the project. Another comment was that the financial targets were unrealistic, that "Chevrolet wanted a Porsche on a VW budget." Although the approaches that were taken began to yield significant improvements from a cost perspective, they fell short of the established goals, and morale began to decline. The final blow came when it became obvious that there was no available power-train that would be acceptable for the vehicle. To the best of anyone's knowledge, very little of the project's work has been utilized in other programs to date.

## **OBSERVATIONS**

In spite of the difficulty in making generalizations from a limited set of interviews, a few issues can be

identified from the information received on these projects. One observation is that successful projects tended to have high level sponsors, while unsuccessful projects in some cases did not. Although the presence of a sponsor did not guarantee success, it was a common occurrence in the successful projects. Obviously, a sponsor provides credibility to a project, and can assist in obtaining resources and overcoming organizational obstacles.

Secondly, although several of these projects were termed unsuccessful from the standpoint of being accepted for production in their targeted vehicle program, they were successful in a broader context. All but one either achieved success in a later vehicle program or have work continuing in the belief that a production application will be identified. It is important to realize that even though a new technology may have many benefits, it may take several attempts to match the technology with a vehicle program that can successfully take advantage of those benefits.

Finally, one of the main factors that seemed to lead to missed opportunities was the relationship to other technologies. In the case of the slot antenna, manufacturing concerns over plastic rear deck lids eliminated the slot antenna from consideration. For single sided-spot welding, a styling change eliminated the main requirement for the technology. It is certainly important for managers to understand how their project efforts relate to other

technologies and to track this relationship in an ongoing manner.

With the basic understanding of each project provided by this overview, the specific results of the survey can be reviewed. That will be the topic of the next chapter.

## CHAPTER 6

### RESULTS OF SURVEY

#### RESPONSE BREAKDOWN

A total of 96 surveys were distributed to individuals that participated in the seven projects. Of these 96 surveys, 84 were returned for a response rate of 87.5%. Two of the 84 surveys were unusable, and had to be omitted from the database. The response breakdown by project is given in Table 6-1.

**Table 6-1: Breakdown of Surveys by Project**

<u>Project</u>	<u>Distributed</u>	<u>Responses</u>
ABS-VI	32	24
Head-Up Display	7	7
Slot Antenna	8	6
Hydroformed Roof Rails	9	8
Multibent Headers	10	9
Single-Sided Spot Welding	10	9
Chey-200	20	19
TOTAL	96	82

In order to handle the survey responses in a numerical fashion, the answers to each question were coded on a numerical scale from 1 to 7, with the left-hand side of the response bar given the value of 1 and the right-hand side of the bar given the value of 7. The responses from each survey were then entered into a statistical analysis program and mean responses were computed along different dimensions

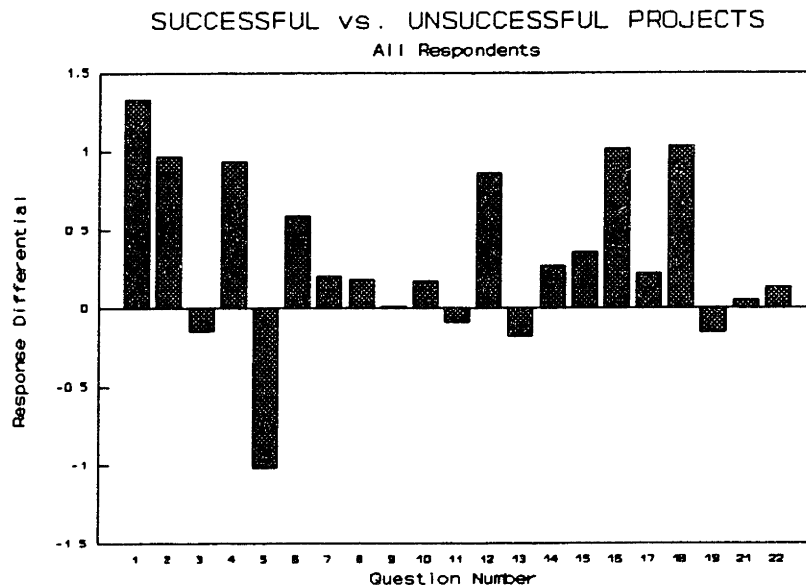


(see Appendix B). The differences between the mean responses along each dimension were calculated, and these "response differentials" were analyzed. The results from this analysis are given below.

## SUCCESSFUL vs. UNSUCCESSFUL PROJECTS

When the survey responses were sorted between successful and unsuccessful projects, the response differential was defined as the mean of the responses on successful projects minus the mean of the responses on unsuccessful projects. The response differentials for each question are graphed in Figure 6-1. As can be seen from this figure, several

**Figure 6-1: Response Differentials of Successful vs. Unsuccessful Projects**



questions (1, 2, 4, 5, 6, 12, 16, and 18) had response differentials that were substantially greater than the other questions. These eight questions can be grouped into four categories: project motivation, uncertainty, organizational impact, and individual roles.

### **Project Motivation**

Questions 1, 2, and 5 were oriented toward the motivating factors behind the project. These questions asked to what extent the project was motivated by new technological capability, newly perceived market demand, and productivity improvements, respectively. The responses and response differentials for these questions are given in Table 6-2.

**Table 6-2: Mean Responses - Project Motivation Questions**

	<u>Project Motivating Factors</u>		
	Tech- nology	Market Demand	Produc- tivity
Successful Projects	5.83	5.20	4.10
Unsuccessful Projects	4.50	4.24	5.12
Response Differential	1.33	0.96	-1.02

An examination of these responses shows that successful projects were motivated to a greater degree by both new technology and newly perceived market demand. As discussed

in Chapter 3, an innovation depends upon the recognition of both demand and capability, and the results here suggest that these two factors both contributed to successful projects. As a group, all projects were more highly motivated by technology (mean response 5.15) than market demand (mean response 4.71). Given that each project originated in an advanced development setting, this suggests that these organizations are more oriented toward technological capabilities than market needs.

A first examination of the degree to which the projects were motivated by attempts to improve productivity may lead to some confusion. Successful projects were motivated to a lesser degree by attempts to improve productivity than were unsuccessful projects. This is surprising given the traditional cost consciousness of the automotive industry in general and the relative cost position of General Motors in particular. However, a possible explanation for this pattern is that in this time frame GM was a product-focused organization. Most capital spending was focused on new product development, and these results may be another indication that the main goals of the organization at this point in time were those relating to improving and upgrading the product line. This was not necessarily the case at all automobile companies. The Japanese manufacturers have a reputation for emphasizing continuous improvement and design for manufacturability in their management systems. This

type of emphasis would result in more emphasis on productivity improvement in advanced development.

**Uncertainty**

Questions 6 and 12 dealt respectively with the amount of uncertainty present in the market acceptance and capital requirements for the projects. Table 6-3 gives the responses and response differentials for these two questions.

**Table 6-3: Mean Responses - Uncertainty Questions**

	<u>Uncertainty Factors</u>	
	Market Acceptance	Capital Requirements
Successful Projects	4.88	5.33
Unsuccessful Projects	4.29	4.48
Response Differential	0.59	0.85

The fact that successful projects showed less uncertainty over market acceptance and capital requirements than unsuccessful projects should hardly be regarded as surprising. Advanced development projects have as one of their main goals the reduction of uncertainty in a number of different areas. An interesting observation arises when it is recognized that although market and capital uncertainty distinguished successful projects from unsuccessful ones, other dimensions of uncertainty such as quality, production

cost, and project timing did not. This may reflect a weakness in understanding marketing and finance issues within advanced development project teams.

### **Organizational Impact**

Question 4 asked the extent to which the roles of organizations within GM were subject to redefinition as a result of the project. Responses from successful projects averaged 5.35 for this question, while the responses from unsuccessful projects averaged 4.41, for a response differential of 0.94. One issue that could certainly have contributed to this difference was the fact that each successful project represented a new business opportunity for a corporate component group, whereas the implementation of unsuccessful projects would have resulted in the substitution of a new technology within an existing business. An organization can be expected to pursue the growth opportunities associated with new business more vigorously than it would the implementation of a new technology within the confines of an existing business line.

### **Individual Roles**

Questions 16 and 18 asked the extent to which the projects had a champion and a high-level sponsor. As was discussed in Chapter 3, these are two of the "critical functions" identified by Roberts and Fusfeld. The response

differentials for these two questions are given in Table 6-4. Champions and high-level sponsors help a project obtain resources, overcome political obstacles, and keep the team members motivated. When these roles are not filled, the chances of project success are diminished. These results once again confirm the importance of these roles to project success.

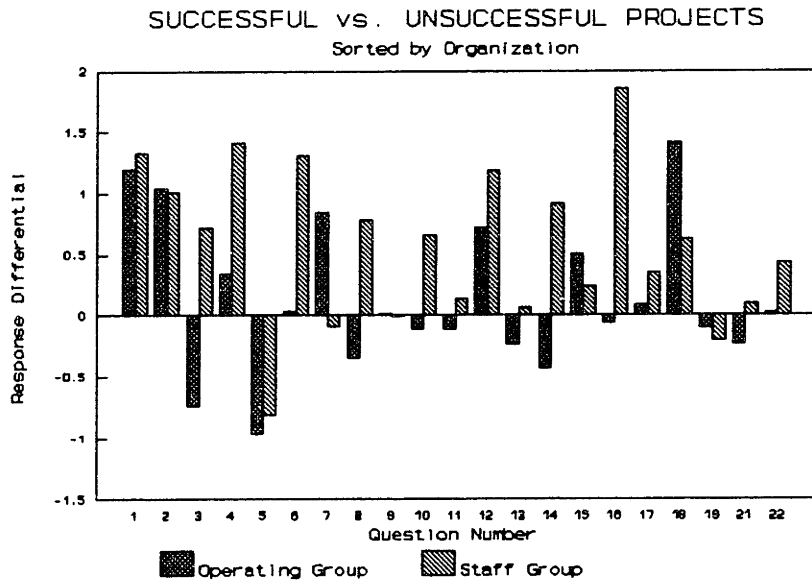
**Table 6-4: Mean Responses - Critical Function Questions**

	<u>Critical Function</u>	
	Daily Champion	High-Level Sponsor
Successful Projects	6.23	5.67
Unsuccessful Projects	5.22	4.64
Response Differential	1.01	1.03

### **STAFF vs. OPERATING RESPONSES**

Of the 82 surveys that were used for the analysis, 42 were from members of the Technical Staffs Group and 40 were from members of various operating divisions. When the response differentials were calculated for each group separately, some interesting contrasts arose. Figure 6-2 shows the response differentials after sorting the data between staff and operating group respondents.

**Figure 6-2: Response Differentials Sorted by Organization**



The two groups shared a similar perspective on several of the questions. In particular, those questions relating to the motivating factors behind the project (Questions 1, 2, and 5) and the importance of quality (Question 9) show high levels of agreement. Substantial differences in responses are discussed below.

### **Organizational Impact**

Question 3 asked the extent to which an existing product, process, or feature was subject to replacement as a result of the project. The response differential for staff respondents on this question was 0.72, indicating that

successful efforts were perceived as replacements for existing items. On the other hand, the response differential for operating group respondents was -0.74, indicating that projects they perceived as replacement efforts were unsuccessful. Such a wide variation in perceptions was unexpected, so the responses were examined in greater detail.

When the mean responses were determined at the individual project level, staff and operating group responses showed relatively close agreement on all projects except the ABS-VI project. This difference can be attributed to the fact that from the staff perspective, ABS-VI was intended to replace antilock braking systems that were being purchased from outside suppliers. However, from the component division point of view, ABS-VI represented a new type of product that was not currently manufactured within the corporation. The high number of respondents from the ABS-VI project therefore masked the relative agreement between staff and operating group responses on most projects.

### **Uncertainty**

Questions 6, 8, 10, 12, and 14 dealt with the level of uncertainty in market acceptance, quality, cost, capital, and timing in the project. As Figure 6-2 illustrates, respondents from the Technical Staffs assigned less uncertainty to successful projects than they did to those that



were unsuccessful. This would suggest that an unacceptable level of uncertainty in the various quantitative aspects of the project contributed to the decision not to move into production. However, Figure 6-2 also reveals that with the exception of capital requirements (Question 12), uncertainty was not a strong differentiator between successful and unsuccessful projects in the operating group responses.

One explanation for this difference in viewpoints could be attributed to lower levels of communication between operating and staff groups. Operating and staff groups are not in close geographical proximity to one another, and it is relatively easy to construct scenarios where an operating group rejects a new technology for production because it is deemed to be unsuitable. Given imperfect communications, individuals from the staff groups may feel that the reason for rejection was not that the technology was inappropriate, but that there was too little time to further reduce the risk and uncertainty associated with the technology. Thus, one group feels that the decision was made with sufficient information, while the other group feels that more time allotted to the project would have allowed the obstacles to be overcome.

### **Market Information**

Question 7 asked how important an issue market acceptance should have been in the production decision. Figure

6-2 shows that responses from staff groups failed to distinguish between successful and unsuccessful projects, while responses from operating groups assigned more importance to this issue for successful projects. It can certainly be argued that individuals from operating groups are closer to the market than those in the technical staffs, and that they are better able to distinguish between desirable and undesirable project features.

Another explanation is related to the "product-driven" orientation discussed earlier in this chapter. Given that the operating group has the final responsibility for deciding what technologies proceed into production, there may be less emphasis placed on projects that fail to be visible to the end customer. This would result in fewer process and productivity-related technologies being accepted by the operating group. With the information available, it is not possible to decide which of these two explanations is more valid.

### **Individual Roles**

A final observation from the data in Figure 6-2 relates to Question 16 regarding the presence of a project champion on a daily basis. Although this strongly distinguishes successful projects from unsuccessful ones in the staff responses, the response differential is very small in the operating group responses. Examination of the responses on

a project by project basis revealed that operating groups felt that both successful and unsuccessful projects had champions. This would indicate that within the operating environment the presence of a champion is not sufficient to assure success. It is also possible that operating and staff responses identifying a champion could be referring to different individuals. This would indicate that the presence of a champion within the Technical Staffs is an important factor for success.

## CHAPTER 7

### DISCUSSION

#### IMPERFECTIONS

Before discussing the implications of the survey in more detail, it is appropriate to introduce some cautions regarding the interpretation of the results. Virtually all surveys are subject to sources of error, and there are three possible sources of distortion in the results as presented in Chapter 6 that may be present to some degree in this study. They are:

- 1) Non-random selection of the projects included in the sample;
- 2) Individual bias of participants from sampling after project success had been determined;
- 3) Small sample size.

#### **Non-Random Sample**

As described in Chapter 4, the projects included in the survey were chosen because they had reached a point in the development cycle that allowed serious pursuit of a production-intent application of the technology. In addition, the decision on whether or not to use the new technology had been made. This method of project selection was used in order to obtain an objective measure of project success or failure. However, when compared against the project

portfolio of an advanced development activity, it introduces some selection bias. Many advanced development projects may never reach the point where such an effort is made. Therefore, the only projects that were selected had by nature experienced a great deal of technical and organizational success in order to reach the point where they would be included in the survey.

Another non-random bias in the sample relates to the sources of information on potential projects for inclusion in the survey. The projects were identified predominantly through discussions with individuals at Advanced Engineering Staff. This tends to introduce a bias toward projects embodying new technology. If the primary contacts had been located in other organizations, a different list of projects would have been generated that may have had more emphasis on new market needs than on new technology.

### **Participant Bias**

It is commonly accepted that questioning individuals after their involvement in an activity is less desirable than obtaining their responses in an on-going fashion while the activity is taking place. Recollections of individual events can be affected by the passage of time and by the overall results that the activity obtained. Since this survey was taken after each project had attempted to be included in production, a tendency may have existed on the

part of respondents to overlook or overemphasize problems depending on the end results that were achieved.

### **Small Sample Size**

As Table 6-1 revealed, fewer than ten responses were obtained from five of the seven surveyed projects. This did not represent a poor response rate, but rather reflects the fact that the projects involved a relatively small number of people. In addition, the process-related projects had a high degree of overlap in individual participants, so the responses on those projects cannot be regarded as completely independent.

When the responses were sorted between successful and unsuccessful projects, the 82 responses were almost equally divided. Since it cannot be assumed that the responses followed a normal distribution, many statistical tests for significance could not be appropriately applied. In analyzing the responses, emphasis was therefore placed on straightforward calculations of mean responses along the dimensions of success and operating/staff group membership.

## **IMPLICATIONS**

In spite of the imperfections mentioned above, the study has revealed some interesting differences between successful projects and unsuccessful projects. These differences are particularly interesting when there is a

high degree of consistency between the literature, the information obtained through the individual interviews, and the survey results.

### **Project Motivation**

As developed in Chapter 3, an innovation is the successful implementation of a new technology to meet a market need. This was confirmed in the results of the survey, where successful projects exceeded unsuccessful ones in the degree to which they were motivated by a new technological capability and by a newly perceived market demand. This was particularly evident in the case of the ABS-VI project, where a technology originally developed for another application was adapted to meet the requirements of a rapidly growing market segment for low-cost antilock braking systems.

In general, the surveyed projects were motivated less by the recognition of a market need than by the development of new technology. The ability to anticipate market demand several years into the future is a daunting task, and is one of the reasons why the industry is focusing on shortening development cycles. Nevertheless, increased efforts to bring market information into the advanced development environment should prove beneficial. Techniques such as rotating advanced development engineers through operating group assignments, joint planning and funding of advanced

development projects, and methods to quantify customer needs such as Quality Function Deployment are possible ways of improving the sensitivity of advanced development groups to market needs.

Another observation with respect to project motivation can be related to Abernathy's concept of de-maturity. In a mature industry, it is expected that most innovations would be process and productivity related. The results of the survey indicated that projects that were oriented toward productivity improvements were less likely to be successful, providing one indication that the automotive industry has possibly entered a stage of de-maturity. Product innovation became a powerful competitive factor in the marketplace, and therefore received the most attention from the organization during this time frame. The cost of this orientation surfaces in a temporary reduction in the number of productivity-related projects that are implemented. Design for manufacturability techniques are important tools that can combine both product and productivity improvement goals in an attempt to avoid a lapse in the rate of productivity improvement during rapid product improvement stages.

A final aspect of project motivation involves the aspect of new business efforts. Within the corporation's component divisions, there is typically more interest in expending valuable engineering resources on a new business area than there is in making substantial changes to an



existing business area that appears to be competitive and secure. There was a substantial difference between operating and staff responses in the extent to which successful projects were perceived as replacements for existing products, processes, or features. Staff respondents were more likely to perceive this was the case for successful projects, and operating personnel were more likely to respond in this fashion on unsuccessful projects.

### **Uncertainty**

As would be expected, uncertainty played a role in determining which projects succeeded. Given the level of investment required to produce a new vehicle, high levels of uncertainty in any portion of the program introduce an unacceptable amount of risk. Uncertainty in market and capital requirements were pronounced differentiators between successful and unsuccessful projects. Uncertainty played a much greater role in the staff environment than it did in the operating environment. This may be due to involvement of staff personnel at earlier stages of the program, where uncertainty is highest. Another factor may be the role of the operating personnel in reducing uncertainty through the use of the normal production qualification process.

Another aspect of uncertainty surfaced in the interview process. Four of the seven projects were chosen to represent unsuccessful projects in that they were not included in

the targeted vehicle program. Of these four, three achieved success in either another vehicle program or in a different area of the targeted program. The learning process that occurs once the advanced development group begins working closely with the operating group can often provide a new set of alternatives for consideration, some of which may prove more attractive than the one that was originally pursued.

### **Critical Functions**

In the overall results, the roles of project champion and high-level sponsor were found to be highly present in the successful projects. The importance of these roles has been established in many previous studies. A champion provides the daily guidance, energy, and advocacy for a project to keep it viable, particularly in the early going. A high-level sponsor provides political power, credibility, and aids in obtaining resources. Both roles are extremely valuable in a large organization that must evaluate a large number of alternatives for future efforts.

One unexplained difference between staff and operating group responses concerns the role of the project champion. Although this was a strong indicator of success among the staff responses, there was virtually no indication that this was true among the operating group responses. The role of champion was present in both successful and unsuccessful projects from the operating perspective. This would

indicate that although necessary, a project champion is not sufficient to achieve success.

## CHAPTER 8

### CONCLUSIONS

The process of developing new technology for the automobile is a long and complex one. Advanced development projects generally have as their ultimate goal the incorporation of their technology into the production product or process. Projects that are eventually successful overcome a variety of obstacles throughout the development cycle. The decision to include the new technology in a production program represents an important point in the implementation of the innovation. If this decision is made in favor of the new technology, resources will be allocated and schedules developed to implement the technology in the production environment. Because of the importance of this decision, this thesis has examined some of the issues that affect its outcome.

Innovation represents a powerful competitive weapon in today's automotive industry. When compared to the relatively static state of the industry in the late fifties and early sixties, today's automotive market has a high number of competitors and a rapid rate of technological change. A process of de-maturity has shifted the industry into a phase where innovations in product and process techniques are key success factors.

By combining the existing knowledge embodied in the innovation literature with personal interviews and a questionnaire-based survey, several issues that affect the decision to incorporate new technology into a vehicle are identified. Successful innovations represent the melding of a new technology with a newly perceived market demand. Not unexpectedly, uncertainty plays a key role in the decision process, particularly in the areas of market acceptance and capital requirements. The critical function roles of project champion and high-level sponsor once again surface as key factors for success.

In spite of the fact that staff and operating group personnel worked together closely on the projects, there were substantial differences in perceptions on several issues, including the role of uncertainty in a variety of quantitative issues related to the projects. The impact of a project champion was also substantially different between the staff and operating group respondents.

The projects as a group were significantly more technology-driven than market-driven. Given the importance of market acceptance to the success of the product line, this would indicate that efforts to provide advanced development groups with market information and sensitivity would be beneficial.

Finally, it is noted that success often comes in roundabout and unexpected ways. Of those projects that did

not achieve their initial goal of incorporation into a given product line, three of four either achieved success in another product line or have other applications planned. The process of technological development includes such a wide variety of alternatives that it is extremely difficult to match a new technology with the best application on the first iteration. This provides a strong argument for faster development cycles and the actual market testing of new technologies in small volumes.

The information presented in this thesis will hopefully provide the reader with additional insight into the innovation process in the automotive industry. This insight can be applied to the selection and management of advanced development projects in an attempt to increase the effectiveness of R & D spending. More than ever before, the company that can meet customer needs by effectively harnessing the creative talents of its engineers and scientists will hold a competitive edge in the marketplace.

## APPENDIX A

### SURVEY QUESTIONNAIRE

#### Introduction of New Technology - Questionnaire

Please provide the following information regarding your involvement in the project:

Project Name \_\_\_\_\_

Organization \_\_\_\_\_

Role \_\_\_\_\_

Level of Management: \_\_\_ Non-Managerial \_\_\_ 1st Level

\_\_\_ 2nd Level \_\_\_ >2nd Level

Length of Involvement in Project \_\_\_\_\_

Name (optional) \_\_\_\_\_

Outside Phone (optional) \_\_\_\_\_

For each of the questions that follow, please indicate your response on the scale below each question.

1. To what extent was the motivation for the project driven by a new technological capability?

Not at All

To a Great Extent

--	--	--	--	--	--	--

2. To what extent was the motivation for the project driven by a newly perceived market demand?

Not at All

To a Great Extent

--	--	--	--	--	--	--

3. Was there an existing product, process, or feature that this project was intended to replace?

Not at All

To a Great Extent

--	--	--	--	--	--	--

4. Were the roles of any organizations within GM subject to redefinition as a result of this project? (e.g., lost products, new products, reorganization, new skills, etc.)

Not at All

To a Great Extent

--	--	--	--	--	--	--

5. Was this project intended to improve the corporation's productivity?

Not at All

To a Great Extent

--	--	--	--	--	--	--

6. At the time of the production decision, how much uncertainty was there for the market acceptance of the project?

Much Uncertainty

Little Uncertainty

--	--	--	--	--	--	--

7. Should market acceptance have been an important issue in the production decision?

Not Important

Very Important

--	--	--	--	--	--	--

8. At the time of the production decision, how much uncertainty was there in the project's quality and reliability?

Much Uncertainty

Little Uncertainty

--	--	--	--	--	--	--

9. Should quality and reliability have been important issues in the production decision?

Not Important

Very Important

--	--	--	--	--	--	--



10. At the time of the production decision, how much uncertainty was there in the production cost of the project?

Much Uncertainty

Little Uncertainty

--	--	--	--	--	--	--

11. Should cost have been an important issue in the production decision?

Not Important

Very Important

--	--	--	--	--	--	--

12. At the time of the production decision, how much uncertainty was there in the capital requirement for the project?

Much Uncertainty

Little Uncertainty

--	--	--	--	--	--	--

13. Should the capital requirement have been an important issue in the production decision?

Not Important

Very Important

--	--	--	--	--	--	--

14. At the time of the production decision, how much uncertainty was there in the project timing?

Much Uncertainty

Little Uncertainty

--	--	--	--	--	--	--

15. How could the project timing have affected the overall vehicle program timing?

Beneficial

No Effect

Harmful

--	--	--	--	--	--	--

16. To what extent was there an identifiable individual who championed the project throughout the organization on practically a daily basis?

Not at All

To a Great Extent

--	--	--	--	--	--	--

17. Was the project effectively planned and coordinated?

Not at All

To a Great Extent

--	--	--	--	--	--	--

18. To what extent did the project have a high-level sponsor within the corporation?

Not at All

To a Great Extent

--	--	--	--	--	--	--

19. To what extent were different organizational functions other than product engineering combined into the project team?

Not at All

To a Great Extent

--	--	--	--	--	--	--

20. Please indicate the various functions that were represented in the project team:

- |  |  |
|--|--|
| <input type="checkbox"/> R&D                       | <input type="checkbox"/> Product Engineering |
| <input type="checkbox"/> Manufacturing Engineering | <input type="checkbox"/> Marketing           |
| <input type="checkbox"/> Finance                   | <input type="checkbox"/> Production Workers  |
| <input type="checkbox"/> Service                   | <input type="checkbox"/> Other(_____)        |

21. To what extent was technology transferred between organizations by moving people?

Not at All

To a Great Extent

--	--	--	--	--	--	--

22. To what extent was technology transferred between organizations through procedures such as common planning, objective setting, and review?

Not at All

To a Great Extent

--	--	--	--	--	--	--

**THANK YOU AGAIN FOR YOUR COOPERATION !**

## APPENDIX B

### RESPONSE SUMMARIES

1. To what extent was the motivation for the project driven by a new technological capability?

Overall:	5.1	Slot Antenna:	5.2
Hydroforming:	6.3	Single-Sided Welding:	4.9
Chev-200:	3.4	ABS-VI:	5.6
Head-Up Display:	6.6	Multibending:	5.8
Successful:	5.8	Unsuccessful:	4.5

2. To what extent was the motivation for the project driven by a newly perceived market demand?

Overall:	4.7	Slot Antenna:	3.5
Hydroforming:	4.9	Single-Sided Welding:	3.3
Chev-200:	4.6	ABS-VI:	6.1
Head-Up Display:	4.1	Multibending:	3.6
Successful:	5.2	Unsuccessful:	4.2

3. Was there an existing product, process, or feature that this project was intended to replace?

Overall:	5.0	Slot Antenna:	7.0
Hydroforming:	6.8	Single-Sided Welding:	6.6
Chev-200:	3.1	ABS-VI:	5.0
Head-Up Display:	2.3	Multibending:	7.0
Successful:	5.0	Unsuccessful:	5.1

4. Were the roles of any organizations within GM subject to redefinition as a result of this project? (e.g., lost products, new products, reorganization, new skills, etc.)

Overall:	4.9	Slot Antenna:	5.7
Hydroforming:	5.0	Single-Sided Welding:	3.0
Chev-200:	4.4	ABS-VI:	5.4
Head-Up Display:	4.1	Multibending:	6.1
Successful:	5.4	Unsuccessful:	4.4

5. Was this project intended to improve the corporation's productivity?

Overall:	4.6	Slot Antenna:	2.3
Hydroforming:	6.4	Single-Sided Welding:	4.3
Chev-200:	5.8	ABS-VI:	4.0
Head-Up Display:	2.1	Multibending:	6.0
Successful:	4.1	Unsuccessful:	5.1

6. At the time of the production decision, how much uncertainty was there for the market acceptance of the project?

Overall:	4.6	Slot Antenna:	5.0
Hydroforming:	5.6	Single-Sided Welding:	5.8
Chev-200:	2.7	ABS-VI:	4.7
Head-Up Display:	3.9	Multibending:	6.1
Successful:	4.9	Unsuccessful:	4.3

7. Should market acceptance have been an important issue in the production decision?

Overall:	5.0	Slot Antenna:	4.3
Hydroforming:	4.3	Single-Sided Welding:	3.9
Chev-200:	5.9	ABS-VI:	5.9
Head-Up Display:	5.0	Multibending:	3.0
Successful:	5.1	Unsuccessful:	4.9

8. At the time of the production decision, how much uncertainty was there in the project's quality and reliability?

Overall:	3.9	Slot Antenna:	4.0
Hydroforming:	4.5	Single-Sided Welding:	5.1
Chev-200:	2.8	ABS-VI:	3.8
Head-Up Display:	3.9	Multibending:	4.8
Successful:	4.0	Unsuccessful:	3.9

9. Should quality and reliability have been important issues in the production decision?

Overall:	6.4	Slot Antenna:	6.7
Hydroforming:	6.1	Single-Sided Welding:	6.6
Chev-200:	6.3	ABS-VI:	6.4
Head-Up Display:	5.3	Multibending:	6.6
Successful:	6.4	Unsuccessful:	6.4

10. At the time of the production decision, how much uncertainty was there in the production cost of the project?

Overall:	4.4	Slot Antenna:	5.8
Hydroforming:	4.5	Single-Sided Welding:	5.1
Chev-200:	3.2	ABS-VI:	4.0
Head-Up Display:	4.6	Multibending:	5.3
Successful:	4.4	Unsuccessful:	4.3

11. Should cost have been an important issue in the production decision?

Overall:	5.8	Slot Antenna:	5.2
Hydroforming:	6.1	Single-Sided Welding:	4.9
Chev-200:	6.3	ABS-VI:	5.9
Head-Up Display:	4.4	Multibending:	6.2
Successful:	5.7	Unsuccessful:	5.8

12. At the time of the production decision, how much uncertainty was there in the capital requirement for the project?

Overall:	4.9	Slot Antenna:	5.2
Hydroforming:	5.5	Single-Sided Welding:	5.6
Chev-200:	3.3	ABS-VI:	5.3
Head-Up Display:	5.1	Multibending:	5.6
Successful:	5.3	Unsuccessful:	4.5

13. Should the capital requirement have been an important issue in the production decision?

Overall:	5.6	Slot Antenna:	4.3
Hydroforming:	6.8	Single-Sided Welding:	5.0
Chev-200:	6.0	ABS-VI:	5.6
Head-Up Display:	4.1	Multibending:	6.4
Successful:	5.5	Unsuccessful:	5.7

14. At the time of the production decision, how much uncertainty was there in the project timing?

Overall:	4.6	Slot Antenna:	6.0
Hydroforming:	4.0	Single-Sided Welding:	6.0
Chev-200:	3.5	ABS-VI:	4.5
Head-Up Display:	5.4	Multibending:	4.8
Successful:	4.7	Unsuccessful:	4.5

15. How could the project timing have affected the overall vehicle program timing?

Overall:	4.7	Slot Antenna:	4.7
Hydroforming:	6.0	Single-Sided Welding:	4.8
Chev-200:	3.5	ABS-VI:	5.3
Head-Up Display:	4.0	Multibending:	4.6
Successful:	4.9	Unsuccessful:	4.5

16. To what extent was there an identifiable individual who championed the project throughout the organization on practically a daily basis?

Overall:	5.7	Slot Antenna:	5.0
Hydroforming:	5.3	Single-Sided Welding:	5.8
Chev-200:	5.0	ABS-VI:	6.1
Head-Up Display:	6.7	Multibending:	6.2
Successful:	6.2	Unsuccessful:	5.2

17. Was the project effectively planned and coordinated?

Overall:	5.3	Slot Antenna:	5.8
Hydroforming:	5.5	Single-Sided Welding:	5.7
Chev-200:	4.5	ABS-VI:	5.0
Head-Up Display:	6.0	Multibending:	5.9
Successful:	5.4	Unsuccessful:	5.1

18. To what extent did the project have a high-level sponsor within the corporation?

Overall:	5.2	Slot Antenna:	4.5
Hydroforming:	5.0	Single-Sided Welding:	4.9
Chev-200:	4.4	ABS-VI:	5.7
Head-Up Display:	6.7	Multibending:	4.8
Successful:	5.7	Unsuccessful:	4.6

19. To what extent were different organizational functions other than product engineering combined into the project team?

Overall:	6.0	Slot Antenna:	6.0
Hydroforming:	5.9	Single-Sided Welding:	5.7
Chev-200:	6.3	ABS-VI:	6.0
Head-Up Display:	5.7	Multibending:	5.8
Successful:	5.9	Unsuccessful:	6.0

21. To what extent was technology transferred between organizations by moving people?

Overall:	3.7	Slot Antenna:	3.4
Hydroforming:	2.7	Single-Sided Welding:	2.0
Chev-200:	4.9	ABS-VI:	4.3
Head-Up Display:	3.7	Multibending:	2.1
Successful:	3.7	Unsuccessful:	3.7

22. To what extent was technology transferred between organizations through procedures such as common planning, objective setting, and review?

Overall:	5.1	Slot Antenna:	6.4
Hydroforming:	4.9	Single-Sided Welding:	5.2
Chev-200:	4.6	ABS-VI:	5.0
Head-Up Display:	5.1	Multibending:	5.6
Successful:	5.2	Unsuccessful:	5.0