INSTITUTIONS, INNOVATION, AND INFORMATION INFRASTRUCTURE: 
THE SOCIAL CONSTRUCTION OF INTELLIGENT TRANSPORTATION SYSTEMS 
IN THE U.S., EUROPE, AND JAPAN 

by 
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M.S. Technology and Policy 
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Submitted to the Department of Political Science 
In Partial Fulfillment of the Requirements for the Degree of 

Doctor of Philosophy (PhD) in 
Technology, Management and Policy/Political Science 
at the Massachusetts Institute of Technology 
June 1996 

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Institutions, Innovation, and Information Infrastructure:
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ABSTRACT

This dissertation compares the development of Intelligent Transportation Systems (ITS) in five parallel development programs in the U.S., Europe, and Japan. ITS is the application of information technology to road transport to create a vehicle-road-communication system that increases traffic efficiency and provides new information services.

In comparing these ITS programs, the dissertation investigates two theoretical issues. First, it seeks to understand the development of large technical systems. ITS is representative of a large technical system, a system in which multiple independent organizations collaborate in a single functional entity. The dissertation seeks to identify factors that shape the development of large technical systems. It investigates why different programs pursuing the same technical vision of a system produce different outcomes.

Second, this dissertation seeks to understand the role of institutions in public policy. Considerable research exists on how constitutionally-defined, national-level institutions shape public policy. This dissertation explores the effects of lower-level institutional structures specific to sectors (e.g. the road transport sector.)

In the study the argument is made that the development of large technical systems is influenced by the institutionalized organization of resources in the surrounding sector. The sectoral institutions that organize resources affect outcomes.

The dissertation proposes a model of sectoral institutions to explain system development. Development begins with a technical vision of a system to be developed. This technical vision defines a pattern of resource needs. Development requires three kinds of resources: funding, expertise, and authority. Three kinds of sectoral institutions organize these resources, conditioning resource availability and defining the sets of actors that control the resources. Frameworks for funding define pools of funding and the actors that control the allocation of
funding; the division labor defines the available expertise and its distribution among a set of actors; and governance structures define the domains of authority and the actors that exercise authority over them. In order to obtain the needed funding, expertise, and authority to realize their technical vision, system developers must build coalitions of the institutionally-defined sets of actors controlling resources. In building these coalitions, development is shaped.

This model of sectoral institutions explains many of the differences between ITS development programs. These differences include the early bifurcation of the Japanese development program into incompatible technology designs, the emphasis on operations-oriented activities in the U.S., and the emphasis on research-oriented activities in some European programs. This model also makes sense of some of the surprising results of the ITS programs. For instance, despite the decentralized nature of U.S. political institutions, the centralized governance structure of the road transport sector allowed the ITS developers in the U.S. to initially design the most centralized system architecture of any program.

Thesis Supervisor: Joseph Sussman
Title: Professor of Civil & Environmental Engineering
Acknowledgments
Many thanks go to my friends and colleagues who helped me research and write this thesis. First and foremost among these is Joe Sussman, who has been a patient teacher, critic, and collaborator on this and many other projects. I have learned much about technology policy both from listening to what he says and from observing what he does. His integrity and respect for others set a high standard that I aspire to in my own professional activities.

I believe that all members of my dissertation committee share a commitment to bridging the gap between social and technical knowledge and practice. Tom Hughes and John Ehrenfeld have been among this most committed to this. Tom Hughes has given me great intellectual and professional assistance over the years. I have also been deeply impressed by his tireless promotion of curriculum innovation at MIT. John Ehrenfeld has been a broad-minded and progressive force in MIT's Technology and Policy Program. I have benefitted from my interactions with him, beginning with our collaboration in a seminar on critical theory and technology policy.

Two members of my committee gave me valuable training in social science. I profited greatly from Nick Ziegler's depth of understanding of comparative case studies. Harvey Sapolsky helped me to bring out the insights in the conclusion. I am honored to have been associated with two such outstanding social scientists.

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway Transportation Officials</td>
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<tr>
<td>AMTICS</td>
<td>Advanced Mobile Traffic and Information System</td>
</tr>
<tr>
<td>CACS</td>
<td>Comprehensive Automobile Traffic Control System</td>
</tr>
<tr>
<td>Caltrans</td>
<td>California State Department of Transportation</td>
</tr>
<tr>
<td>COPILOT</td>
<td>Operating company for Euro-Scout implementation</td>
</tr>
<tr>
<td>CORRIDOR</td>
<td>Cooperation on Regional Road Informatics Demonstrations on Real Sites</td>
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<tr>
<td>DG-VII</td>
<td>European Commission Directorate General VII for Transportation</td>
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<td>DG-XIII</td>
<td>European Commission Directorate General XIII for Telecommunications, Information Industries and Innovation</td>
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<tr>
<td>DRIG</td>
<td>Drive Infrastructure Group</td>
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<td>DRIVE</td>
<td>Dedicated Road Infrastructure for Vehicle Safety in Europe</td>
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<td>EC</td>
<td>European Commission</td>
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<tr>
<td>ERGS</td>
<td>Electronic Route Guidance System</td>
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<td>ERTICO</td>
<td>European Road Transport Telematics Implementation Co-ordination Organisation</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>FTA</td>
<td>Federal Transit Administration</td>
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<tr>
<td>HIDO</td>
<td>Highway Industry Development Association</td>
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<tr>
<td>ISTEA</td>
<td>Intermodal Surface Transportation and Efficiency Act</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transportation Systems</td>
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<tr>
<td>IVHS</td>
<td>Intelligent Vehicle-Highway Systems</td>
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<td>JSK</td>
<td>Association of Electronic Technology for Automobile Traffic and Driving</td>
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<td>JTMTA</td>
<td>Japan Traffic Management Technology Association</td>
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<tr>
<td>MITI</td>
<td>Ministry of International Trade and Industry (Japan)</td>
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<td>MOC</td>
<td>Ministry of Construction (Japan)</td>
</tr>
<tr>
<td>MRT</td>
<td>German Ministry of Research and Technology (BMFT)</td>
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<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<tr>
<td>NPA</td>
<td>National Police Agency (Japan)</td>
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<tr>
<td>POLIS</td>
<td>Promoting Operational Links with Integrated Services through road traffic informatics between European cities</td>
</tr>
<tr>
<td>PROMETHEUS</td>
<td>Program for European Traffic with Highest Efficiency and Unprecedented Safety</td>
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<tr>
<td>RACS</td>
<td>Road Automobile Communication System</td>
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<tr>
<td>SCC</td>
<td>Strategic Consultative Committee</td>
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<tr>
<td>SECFO</td>
<td>System Engineering and Consensus Formation Office</td>
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<tr>
<td>VERTIS</td>
<td>Vehicle Road Traffic Intelligent Society</td>
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<tr>
<td>VICS</td>
<td>Vehicle Information and Communication System</td>
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### Time Line

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tr>
<td>1967</td>
<td>FHWA begins ERGS experiment in the U.S.</td>
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<td>1971</td>
<td>ERGS technical field test denied funding</td>
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<td>1973</td>
<td>Japan's MITI launches CACS technical field test</td>
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<tr>
<td>1979</td>
<td>CACS technical field test completed</td>
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<tr>
<td>1979</td>
<td>Bosch performs ALI experiment in Germany</td>
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<tr>
<td>1984</td>
<td>Siemens and Berlin negotiate LISB technical field test</td>
</tr>
<tr>
<td>1984</td>
<td>Japan's Ministry of Construction plans RACS operational test</td>
</tr>
</tbody>
</table>

**1985**
- Spring: EUREKA pan-European framework for funding created
- September: German Ministry of Research and Technology (MRT) supports LISB
- October: PROMETHEUS Brainstorming sessions at Daimler-Benz

**1986**
- June: PROMETHEUS supported by EUREKA framework for funding
- September: European Commission's DRIVE Planning Exercise Complete
- October: Kick-off of PROMETHEUS
- October: Highway Technology Conference in California

**1987**
- Japan's National Police Agency plans AMTICS operational test
- April: PROMETHEUS-DRIVE reconciliation
- July: EC formally proposes DRIVE program
- November: PROMETHEUS Symposium for Suppliers
- November: First informal IVHS planning meeting at FHWA

**1988**
- March: Mobility 2000 members meet in Berkeley, California
- June: PROMETHEUS research projects selected
- June: European Union formally adopts DRIVE

**1989**
- January: DRIVE research begins (3 year duration)
- Spring: LISB technical field test begins in Berlin
- Mobility 2000 holds quarterly meetings
- AASHTO supports U.S. national program
- Winter: PROMETHEUS reorganizes to emphasize product development

(Continued)
Time Line  (Continued)

1990  
March  Secretary of Transportation supports U.S. IVHS program  
March  Mobility 2000 holds Dallas Conference  
May  National Leadership Conference launches IVHS AMERICA  
       Congress appropriates $20m funding  
August  IVHS AMERICA incorporated  

1991  
March  LISB technical field test completed in Berlin  
July  IVHS AMERICA strategic planning committee formed  
September  PROMETHEUS first demonstration in Turin  
Fall  VICS launched to unite RACS and AMTICS in Japan  
December  U.S. ISTEA legislation provides $660m over six years  

1992  
January  DRIVE II begins  
May  IVHS AMERICA Strategic Plan Published  

1993  
November  VICS public demonstration  

1994  
January  VERTIS created  
Summer  COPilot Incorporated in Germany  
November  PROMETHEUS terminates with final demonstration  

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Chapter 1

INTRODUCTION

This study examines and compares programs around the world attempting an innovation in surface transport called "Intelligent Transportation Systems" or "ITS." ITS is a technology to realize "smart cars" and "smart roads." It consists of the application of information, communication, and automation technologies to road transportation to transform the passive road network into a responsive traffic system. Where previously there were isolated drivers on passive roads, ITS would link vehicles and roads into an integrated system. Proponents claim that ITS could radically improve road transportation by increasing traffic capacity on existing roads, improving safety, and enabling new information services to drivers. In the 1970s and into the 1990s five ITS development programs were launched in the U.S., Japan, and Europe.

This study compares the history of development of those five programs. The study seeks understanding into how social factors shape the development of large technical systems and, more broadly, how institutions shape public policies. By examining and comparing ITS development programs this work shows how institutions condition both technical change and the policy process.

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The knowledge sought here is both analytical and practical. On the one hand, the study offers concepts and relationships with which to analyze socio-technical change, to explain why certain outcomes occurred, and to (cautiously) predict future events. On the other hand, it offers methods to guide intervention in socio-technical change and to identify factors amenable to human control. Thus it aspires to both theoretical and practical relevance, seeking not just to interpret the world but to suggest methods by which to change it.

This study builds on the concept of a large technical system. A large technical system combines technology and organizations into a functional entity. Combining technology and social organization, these are also called socio-technical systems. Paradigmatic examples of large technical systems are electric power generation and distribution networks\(^1\), telephone systems\(^2\), and air traffic control systems\(^3\). These spatially-extended and functionally integrated socio-technical systems often constitute the basic infrastructure for social activity.\(^4\)

Two traits of large technical systems match the purposes of this study. First, they are large enough to have broad social impacts. They involve many people and organizations, enormous material resources, and may take years to develop. Unlike a narrower technology, like kidney dialysis machines for example, a single large technical system can cause society-wide change. Second, they are coherent enough to allow for intervention. The many different parts of each system connect to each other and interact as a functional entity. As coherent entities, they can be subject to intervention through planning, control, and design. They differ from, say, printing technology, which has broad social impacts but does not lend itself to central planning

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and intervention. Large technical systems illustrate both how socio-technical change occurs and the methods available to intervene in such change.

Intelligent Transportation Systems (ITS) are a large technical system with these characteristics. Mobility is a fundamental human need, and ITS's changes to roads and vehicles could affect nearly every person in the world. Even an examination of only the changes occurring to the relationships between governments, private firms, and universities can say much about socio-technical change. Furthermore, the technology has developed in a planned manner and offers insights into how socio-technical change is planned and directed. ITS developers used a host of practical methods in order to realize their vision; these methods can be codified for dissemination and use by other system developers elsewhere. Thus the ITS development program throughout the world offer much material for gaining both analytical and practical knowledge.

ITS also offers methodological advantages for study. The ITS programs show how the same idea unfolds in different social contexts. Most programs in the U.S., Europe, and Japan trace back to a common technical vision tested in the U.S. around 1970. In the ensuing decades parallel programs on three different continents pursued that vision. This parallelism allows for comparison across cases to reveal the effects of social context on technology development.

ITS's fast-paced evolution (particularly in the U.S.) also offers methodological advantages for study. Much as a geneticist studies fruit flies because of their rapid development, ITS is

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attractive because it has raced from conception to widespread test and early deployment in a few years. This has allowed the author to work as a participant observer during much of development. Collaborating closely with the faculty at the Massachusetts Institute of Technology who have helped launch the program, the author attended many of the key meetings in the U.S. program where development decisions took place. Together with the parallelism, the speed of development and the author's privileged access make ITS especially well-suited for study.

This inquiry took the form of a single question: What factors most influence the development of Intelligent Transportation Systems? The study attempts to answer that question. It examines how and why these development programs were launched and the factors that shaped their development and their outcomes. The answer, in turn, offers practical knowledge into how we more effectively develop large technical systems.

The answer takes the form of a model of sectoral institutions. Sectoral institutions are enduring social structures that organize resources within a policy or industry sector. As system developers pursue a technical vision of a system, their activities are shaped by the availability and organization of resources in the surrounding sector. Sectoral institutions condition resources availability, and thereby they condition system development. An understanding of sectoral institutions clarifies many of the social influences on large technical system development.

Chapter 1: Introduction
In addition to the theoretical insights afforded by ITS programs, these programs are also interesting in their own right. First, they constitute a major initiative in transportation and technology policy and, as such, they are historically significant. This study documents the history of their conception and development.

Second, the ITS programs contradict common stereotypes about national policy styles. The U.S. program is a government-funded, top-down, centralized effort based on significant long-term planning. The government has explicitly supported private industry, going so far as to perform market analyses. How is it that the U.S. program resembles such an extreme case of state-led industrial policy?

The European and Japanese programs also contradict stereotypes about national policy styles. In Europe much initiative has come from the private sector. The reality in Europe more closely resembles the stereotypical American approach of market-led development than of state-supported initiatives. In Japan, a land famous for its consensual decision-making, system development has been hindered by deep and enduring rivalries between programs. More than other programs, the Japanese have had difficulties in cooperation. If in a broad way they embody the characteristics of all large technical systems, in their details the different ITS programs contradict our stereotypes of national policy styles. This study makes sense of these puzzles.

Finally, the ITS programs represent technological gambling on a grand scale. The U.S.
program received a billion dollars of federal funding not because ITS offered benefits, but because it offered *potential* benefits. Perhaps the technology would revolutionize transportation, or perhaps it would have little or no impact. In Europe and Japan governments also made large commitments with little concrete evidence of transportation benefits. All programs were based on speculative estimates of return on investment. This work will seek to explain these patterns of investment.

The study is intended to appeal to a variety of audiences. First, readers interested in socio-technical innovation and the development of large technical systems should find it relevant. As the literature review in the next chapter shows, theories on this topic abound. This study of ITS seeks to contribute to that body of knowledge by offering new insights into how institutions affect system development.

Second, people concerned about intervening in socio-technical change can learn from this work. The government planner may improve his ability to design technological infrastructure. The business strategist may improve her ability to bring complex innovations to market. The citizen activist may improve her ability to influence development to reflect the public interest.

Third, political scientists interested in the effects of institutions on public policy should find topics of interest here. This study illuminates the constraints imposed by institutions on the policy process, as well as the freedom for action that exists within those institutional

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constraints. It examines how the institutional structures particular to a policy or industrial sector shape the policy process.

Finally, ITS policy-makers should find the account of events contained here relevant. This study documents the key events in each program and illuminates the policies of the U.S. program. With its record of the past and some predictions for the future, this work may assist ITS policy-makers plan for the future.
The Technology: Intelligent Transportation Systems (ITS)

Most of this study recounts the histories of development programs in Intelligent Transportation Systems (ITS) from around the world. To understand the programs it is important to understand their common technical vision of ITS.

ITS was first developed in a U.S. research program around 1970. The ITS technical vision was 1) a vehicle-roadside communication link 2) making possible systemic capabilities of information-sharing to 3) provide individual route guidance and area-wide traffic optimization.

This technical vision best be comprehended by examining it from multiple perspectives. ITS can be seen from four different views:

- technology,
- system functionality,
- social relationships, and
- history.

First, ITS is a class of technologies applied to road transportation. To date, road transportation has been largely based on mechanical and civil engineering technologies, with mechanical cars driving on concrete and asphalt roads. ITS applies computers, communications, and automation to this existing infrastructure. Vehicles would be equipped with on-board computers that could read digital road maps from compact discs. Communication technology would provide drivers with real-time information beyond what is
available from road signs. Roadside sensors would measure traffic flows, the information would be collected at a central computer, and traffic lights and freeway controls would maximize flows through the network. ITS would apply a host of new technologies to every aspect of surface transportation.

Second, ITS can also be understood in terms of its functionality. ITS would convert road infrastructure from a *passive network* to an *adaptive system*. The road infrastructure in the U.S. and other countries in 1980 constituted a passive network unable to adjust to fluctuations in transportation demand. ITS would change it to an adaptive system. Traffic sensors would measure activity and detect incidents, allowing traffic control centers to optimize vehicle flows on the entire road network. Travelers would receive information about travel conditions on the entire network and would be advised as to the best route to their destination. Everywhere information would be gathered, processed, and distributed to allow for improved operation of the existing physical infrastructure.\(^5\) Figure 1-1 shows a schematic illustration of an intelligent transportation system.\(^6\)
Figure 1-1
Intelligent Transportation System
In launching programs in the 1970s, 1980s, and 1990s, ITS supporters claimed that this system functionality would provide many benefits. ITS was predicted to increase the capacity of existing roads by increasing their efficiency, thereby allowing more vehicles to travel on the same physical road system. It would render travel safer by communicating vital traffic information to drivers. It would allow for useful new information services for travelers, who would have an information console at their disposal in their private automobile or commercial vehicle. It would reduce the environmental damage caused by road transportation by rendering travel more efficient, smoothing traffic flows, and reducing unnecessary and circuitous travel.

A third perspective for understanding ITS, besides the technical and functional perspectives, is that of social organization. ITS is more than technology; it is also people and organizations. To the technical links between vehicles and roadways would correspond social links between the organizations responsible for these components. To link cars and roads, public authorities would have to cooperate with automakers and electronics firms. To implement a nationally-compatible system in different cities, national governments would have to cooperate with local governments. To justify investment in roadside infrastructure, consumers would have to purchase in-vehicle systems. At the level of social organization, ITS would create a web of cooperative links and interdependencies among previously autonomous firms, agencies, and consumers.

Implicit in this social organization perspective is the fourth perspective, that of history. ITS
development in the U.S., Europe, and Japan was not undertaken in a vacuum; rather, each program developed in a different historical context. That context consisted of organizations, installed infrastructure, and established modes of work and barriers to cooperation inherited from the previous transportation activities. The U.S. national program began in the context of the federal highway sector. Japanese programs evolved in three different national ministries. European programs unfolded at both the national and European level. In each case, the historical context provided opportunities that facilitated development and barriers that inhibited it. Much of this study traces the interaction between the ITS technical vision and the existing social organization from the past.

All four of these perspectives promote an understanding of what ITS is and how it developed. In terms of technology and functionality, ITS consists of the application of information-related technology to existing networks to achieve system functions. In terms of social organization, ITS is a system of social links between autonomous organizations. And as a historical development, ITS was a novel activity unfolding in a context rich with inherited players and established practices.
Organization of the Study

This study is structured in eight chapters. Following this introduction, Chapter Two surveys the literature on large technical system development and institutions in the policy process. This literature review discusses the strengths and weaknesses of existing theories and identifies a gap in the existing literature. The model of sectoral institutions proposed in this study attempts to fill that gap.

Chapter Three then explains the theoretical contribution of this research. It presents a four-part model of "sectoral institutions" that explains outcomes of large technical system development in terms of the institutionalized organization of expertise, authority, and funding. This chapter also presents the research design used in the study, a comparison across case histories of parallel ITS programs on three continents.

Chapter Four applies the sectoral institutions model to the ITS technical vision. It "unpacks" that vision into its component parts and documents the historical events by which this technical vision diffused from the U.S. to Japan and to Europe (and back to the U.S.) Since five ITS programs on three continents all pursued this same technical vision, the analysis provides the basis of similarity across the case histories that follow. When seen through this matrix of similarity, the differences between programs stand out.

Chapters Five, Six, and Seven contain the individual case histories of the Japanese, European, and U.S. ITS programs. With three different programs in Europe, a total of five ITS

Chapter 1: Introduction
programs are documented in these three chapters. Case histories are presented according to the logic of the model of sectoral institutions. They begin with a discussion of the sectoral institutions that structured the development process. Then they trace the process by which the ITS technical vision was pursued within those institutions.

Chapter Eight compares the programs and draws some conclusions. Comparison reveals how the different sectoral institutions structuring each program influenced outcomes. This chapter also summarizes the contribution of this study to knowledge of technology development and of public policy.

Through this study the history of ITS is recorded and analytical and practical insights into large technical system development are obtained. The next chapter surveys the existing literature to which this work seeks to contribute.
Chapter 2

LITERATURE REVIEW

Like all research this study attempts to make a contribution to knowledge -- in this case to knowledge about the development of large technical systems and about public policy. This chapter summarizes a variety of different theoretical perspectives that inform large technical system development. The next chapter presents the model of "sectoral institutions" developed in this research.

Studies of the development of large technical systems have been pursued in many disciplines. The various disciplinary perspectives include political science, the history of technology, developmental economics, technology policy, organizational sociology, systems analysis, management, and the social construction of technology.

Writers in different disciplinary perspectives have asked different questions and have employed different analytical tools in their studies. They have sought to explain topics such as programmatic success and failure, system development, system accidents, and system optimization. Their analytical frameworks have included rational calculation, bureaucratic
politics, political institutions, and system complexity. Although dispersed in many domains, taken as a whole this literature offers a wealth of insights.\textsuperscript{16}

This review groups the literature on large system development into four general perspectives. These are:

- the rational actor perspective,
- the process perspective,
- the system perspective, and
- the institutional perspective.

In what follows, each of these is described, its application to large technical system development is reviewed, and its strengths and weaknesses are examined. To the extent that each model offers practical techniques, these are described as well.

The chapter concludes by identifying a gap in the literature. There are few sub-national institutional models of national policies. Existing literature sheds little light on how institutions within a particular policy sector or industrial sector affect the development of large technical systems. It is this gap in the literature that this study seeks to fill.

Table 2-1 shows the structure of the literature review. Each section in the chapter examines a column in this table corresponding to a different theory of large system development.
Table 2-1: Theoretical Perspectives on Large Technical System Development

<table>
<thead>
<tr>
<th>Main Concepts</th>
<th>Rational Actor</th>
<th>Process</th>
<th>System</th>
<th>Institutional</th>
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<td>Practical Technique</td>
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Rational Actor Perspective

The rational actor perspective is one of the most widely invoked intellectual frameworks for explaining and guiding human action. Although most frequently used in economics, other fields apply it widely as well.

The rationality of this perspective is that of means and ends, or "instrumental rationality." An actor with given preferences may choose from a given set of possible actions. Each action yields an expected outcome that can be evaluated in terms of the actor's preferences. Rational action consists in choosing that action whose expected outcomes is most preferred. The rational actor selects among given means to achieve a given end.

Relative to large technical systems, this perspective explains development as a rational means to achieve some goal. This frequently takes the form of a cost-benefit analysis in which a system's contribution to the achievement of some goal is measured in terms of benefits. These benefits can be compared to the costs of system development. Should a potential system offer a better cost-benefit ratio than alternative approaches, then it is chosen. This basic perspective can take many variations. For example, in his work *Applied Systems Analysis*, Richard de Neufville explores a variety of methods for rational decision-making. All of them, however, build on the basic means-end logic of the rational actor perspective.

The rational actor perspective is both the most significant and the least significant perspective for large technical systems. It is the most significant insofar as it is so widely used in
universities as the foundational intellectual framework to teach technology and policy practitioners. Few engineers or administrators participating in development have not received months or years of training in system analysis, operations research, microeconomics, decision analysis, and other techniques deriving from the rational actor perspective.

This perspective is by far the predominant one among practitioners. Most large technical system development projects include cost-benefit analyses. One survey of such reports can be found in Linda Cohen and Roger Noll's work *The Technology Pork Barrel*, in which the authors examine the cost-benefit analyses that accompanied six large technology development programs. In each program, these analyses showed that the technology to be developed was an efficient means to a desired end.

Anyone educated in a university program for business or policy, or anyone reading official documents for large technical system development, might conclude that no other theoretical perspective exists. The predominance of the rational actor perspective is overwhelming. For this reason it can be ranked as perhaps the most significant intellectual framework for large technical system development.

Yet, it is also the least significant perspective. Among those who *study* large technical system development rather than practice it, the rational actor perspective has less appeal. It simplifies development to such a degree that it eliminates much that is relevant and interesting. For this reason it is arguably the least significant of all. Indeed, aside from planning studies the

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rational actor perspective is rarely used in studies of large technical systems.

The weakness of the rational actor perspective lies in its assumptions. It builds on a number of assumptions that are not met in large system development. These can undermine both the model's explanatory and normative powers.

One fundamental assumption is that of certainty. The rational actor perspective assumes that information about costs, benefits, and technical feasibility are either known with certainty or can be estimated with certainty. Uncertainty, if admitted at all, is conceptualized as as a probability distribution that can be reduced to an expected value. The variables needed for rational calculation are known, and their value or probability distribution is known with certainty.

This assumption of certainty is inappropriate for development. Development is an "emergent" process in which much information only becomes available over time. At any point in time the information needed for rational calculation may not yet be available. Indeed, developers may not even know what information will be required for rational decision-making; not only are the values of variables unknown, the very variables themselves may only be defined during the development process. This problem of emerging information is recognized enough to have earned a name -- the "unknown unknowns" (or "unk-unks.") These are factors figuring in development that are only discovered during development and that must first be understood and conceptualized before being measured. The appearance of unknown variables can be

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anticipated, but the definition of those variables and their values cannot. Being undefined, these factors cannot be included in a rational calculation of means and ends. In its assumption of certainty the rational actor perspective ignores this emergent property of development.

The rational actor perspective also assumes that development is performed by a unitary decision-maker. In its assumption of a unitary decision-maker, the perspective takes a "big picture" approach, treating all developers as a single actor pursuing a single goal. A system, however, is usually a multi-actor (social) entity. System development involves multiple groups with different goals and preferences. Instead of one rational actor there may be many, and their combined rational actions may lead to developmental outcomes that are far from rational in their totality. The process perspective, discussed below, addresses these issues.

Finally, the rational actor perspective ignores the context within which decisions are made. That context, however, may pre-define many of the goals, means, problems, and opportunities that ultimately shape rational decision. Rational action may be merely the execution of a larger program defined by the context. The institutional perspective, also discussed below, focuses on how social structures shape development.

The great strength of the rational actor perspective lies in its practical application. As noted above, this perspective offers practical methods in the form of cost-benefit analysis, systems analysis, and other quantitative techniques. Admittingly, since the characteristics of large technical system development contradict its assumptions, the utility of these techniques are
limited. Still, they can provide an ideal baseline to guide development.

Some negative implications of this perspective for practice also deserve mention here. First, rational actor methods may obscure the possibility of changes to the context of development. Since the model takes goals and choices as given, its practical insights concern efficient action in the existing world, not changes to that world. As one primer on rational action policy methods clearly states, "... policy analysis is a discipline for working within a political and economic system, not for changing it."\(^20\) Similarly, the rational actor perspective may be best suited to working within a large technical system, not for developing it. Indeed, the use of these methods may obscure the possibility of change.

Second, the practical techniques deriving from the rational actor perspective may be abused. Lacking information about the future, groups may provide estimates that guarantee the rationality of their preferred course of action. Rationality may be used to legitimate some course of action that serves the narrow interests of the proposers. Many system development projects are justified by cost-benefit analyses long before ambiguity has decreased enough to allow for accurate measures.\(^21\) Such speculation about benefits may reflect narrow interests as much as rational analysis.

Thus the rational actor perspective for development relies heavily on assumptions of certainty, unitary decision-making, and context-less action. When these assumptions are met, this model provides a powerful tool for explanation and practice. There can be no better model to assist

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the consumer in the supermarket, for instance. However, given the ambiguity, multiplicity, and contextual influences in development, this model's applicability is limited. Quantitative techniques such as cost benefit analyses may at times serve to give an appearance of rational action than to embody it. Table 2-2 summarizes these points.
| **Main Concepts** | Unitary decision-maker  
|                 | Goal and choices given  
|                 | Instrumental, means-end rationality |
| **Weakness**    | Ignores emergent property of information |
|                 | Ignores multiple decision-makers |
|                 | Ignores context |
| **Practical Technique** | Cost benefit analysis, optimization |
|                 | But: may reinforce status quo |
|                 | may legitimate narrow interests |
The Process Perspective

The rational actor perspective collapses system development in time and in complexity. In assuming certainty, it overlooks the emergent nature of development. In assuming a unitary rational actor, it overlooks the social activity of development in which multiple actors pursue multiple goals.

The process perspective takes these factors into account. Instead of assuming a unitary actor, development is conceived of as the interaction of multiple groups, each possessing their own goals. Instead of certainty, the process perspective accepts unexpected change and participants' limited knowledge. Development consists in groups' pursuit of multiple goals, and its final outcome is the "resultant" of the process.22 Thus development is not the linear realization of one actor's intentions pursued through the most efficient means, but the unpredictable final product of a multi-group process. Although each party to development may act rationally, multiplicity and ambiguity render development unpredictable.

In their essay "The Social Construction of Facts and Artifacts," Trevor Pinch and Wiebe Bijker provide one of the clearest examples of the process perspective of the social construction of technology.23 In their model, technology is the product of a negotiation process among different groups. Each group participating in the design process shapes the technology according to its particular interests, concerns, and interpretations. In their simple example from the history of the bicycle, the groups participating in the design process included sport cyclists, women cyclists, and tourist cyclists. The first group sought to influence the

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bicycle design to allow for greater speed, the next for graceful mounting and dismounting, and the third for safety. Each group imposed different criteria of a good design, pursuing a particular goal for which the technology served as the means. The final design satisfied the multiple criteria of the different social groups.

Michel Callon provides a more complex approach based on the concept of the "actor network." He, too, focuses on negotiations among different interest groups. However, in his account the technology itself is party to the negotiation, imposing limits on some designs and presenting opportunities for satisfying multiple parties in others. Scientific, technical, and social factors all affect each other, and Callon expresses these interrelationships by subsuming all of them under the concept of an actor. His attention is also on more complex technical systems, such as military aircraft and electric vehicles. Still, the model is basically the same: technology development proceeds as a process of intergroup negotiation over an extended period of time. The final outcome is explained as the resultant of this process.

In histories of technology development the process perspective is probably the most widely used explanatory approach. Different variants apply to different aspects of development. Used to explain the political negotiations preceding the launch of a program, it is commonly known as the pluralist perspective of political science. An example of this is Mark H. Rose's account of the political negotiations that led to the launch of the Interstate Highway system. He identifies the interest groups that participated in the debate over highways and the extent to which they shaped the definition of the program. Other authors focus more on the

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bureaucratic politics of development itself. James Logsdon explains the problems of the Space Shuttle as the result of early negotiation process among NASA, the Department of Defense, and other parties that supported the Shuttle program and shaped the spacecraft’s design.\textsuperscript{27} Harvey Sapolsky explains the success of the Polaris system development program by the skill of the project managers in maneuvering among groups.\textsuperscript{28}

This perspective emphasizes free human action or "agency." It explains system development by focusing on entrepreneurial leadership by individuals. In most accounts one entrepreneurial individual or group has a vision of the future and works to disseminate its vision to other groups to launch a program. Programs launch occurs when a large coalition is assembled behind a common vision. One collection of such accounts is Vincent Davis's work, \textit{The Politics of Innovation: Patterns in Navy Cases}.\textsuperscript{29} Another work is Elting Morison's "Gunfire at Sea," which documents the efforts of one officer to introduce new gunsights in the U.S. Navy.\textsuperscript{30} These authors document how entrepreneurial individuals build coalitions around innovative ideas.

A number of practical insights can be drawn from this perspective. Most techniques address the problem of inter-group dynamics, particularly the building of coalitions between groups and the protection of a coalition’s activities from outside interference. In \textit{The Politics of Innovation} Vincent Davis outlines various strategies for building coalitions.\textsuperscript{31} Innovators may build coalitions with their peers at one level in an organization; they may build vertical coalitions with power-holders; or as a last resort, they may build coalitions with outside
groups. Opponents to innovation may engage in similar tactics. Law and Callon focus on exclusion, noting the importance of constructing a negotiation space that excludes parties from development. For them, the practical problem is keeping groups out, not bringing them in. In a variation of this, Sapolsky documents the use of quantitative analytical techniques ("PERT") to exclude outsiders. Polaris missile system developers used these techniques as an image-building tool to intimidate their bureaucratic rivals. This was an extreme case of abusing practical techniques in the rational actor perspective -- but one that worked well in inter-group negotiations.\textsuperscript{32}

The process perspective is not without weaknesses, however. Like the rational actor perspective, it pays little attention to the context within which development unfolds, portraying development instead as a free-form process. In so doing it may overlook the social structures that shape the interactions of goal-oriented agents. Larger structures may provide the rules by which process unfolds, and in some cases those rules may be more significant than the players. System development may be better explained with reference to the rules of the process than with reference to the players in it. Other perspectives emphasize these aspects of development. Table 2-3 summarizes the process perspective.
### Table 2-3: Process Perspective

| Main Concepts          | Multiple groups with multiple goals  
|                       | Program launch is entrepreneurial activity  
|                       | System design is a resultant  
| Weakness               | Exclusive reliance on human agency  
|                       | Ignores context  
| Practical Technique    | Coalition-building  
|                       | Exclusion of outsiders  

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The System Perspective

The third perspective is Thomas Hughes' account of large technical systems development. Unlike the others examined here, the system perspective has been developed with specific reference to large technical systems. Nonetheless, its basic concepts can be explored independently of that particular content.

The system perspective seeks to overcome the perceived inadequacies of conventional intellectual frameworks. Intellectual frameworks such as economics, politics, and engineering both illuminate and obfuscate the activity of system developers. Those frameworks illuminate that activity insofar as they provide concepts and relationships with which to understand. However, insofar as all their categories remain within a single intellectual domain, not extending beyond into other domains, they obfuscate the interconnection between different domains. Since the activity of system developers crosses domains, any intellectual framework that would make sense of those activities must also cross those domains. Hughes states, "...hard intellectual categories such as technology, science, politics, economics, and the social should be used sparingly, if their use leads to difficulty in comprehending interconnection."33

The system perspective offers an all-encompassing intellectual framework. Hughes subsumes all knowledge categories under the broad, high-level concept of a "seamless web." System developers follow causality no matter where it leads, and in so doing they may cross from engineering to politics to science to economics. The intellectual and professional boundaries separating these domains have little meaning for system developers, for practical experience
reveals that different domains are connected in a seamless web. Were developers only to see the world according to one intellectual framework, they would fail to see the relationships that make for success or failure. Were they to restrict their activities to just one domain, they would fail to solve many of their problems. System developers have show a way of “grasping the seamless web.” Likewise, Hughes’ system perspective provides concepts with which to understand what it is they do.

Within this general view of a seamless web, Hughes looks at large technical systems. For Hughes, the defining trait of a large technical system is its unity. A system may have very diverse components, including physical artifacts, organizations, or university research programs, but they all contribute to a unified system goal.

This unity may be functional or administrative. The many components of a system may all serve to together perform a collective function, such as providing electric power for consumers. Investment banks, light bulb filaments, and stock holding companies may all contribute to this function and so may be considered components of a system. Administratively, anything subject to the control of system administrators may be included in the system. Hughes makes this administrative criterion explicit in his discussion of the relationship between the Electric Bond and Share Company (EBASCO) holding company and state regulatory authorities: “I am also inclined to include a few of the various state regulatory authorities as parts of the EBASCO system, if their members were greatly influenced by it. If the regulatory authorities were free of this control, then they should be considered a part of the...
Large technical systems develop by passing through a number of phases. Beginning as inventions, they pass through phases of development, innovation, transfer, growth, competition, and consolidation. The different phases exhibit patterns. Inventions may be radical or incremental. During development the invention becomes integrated into a social, political, and economic context. During innovation a full system is created including manufacturing, sales, and services capabilities. Each phase offers characteristic activities, some of them technical, others organizational, financial, or political.

The dynamics of development manifests itself in a succession of "reverse salients." A reverse salient is some component in a system that lags behind all others and eventually hinders the entire system from further advance. It becomes the focus of attention as system developers seek a solution; often, a solution is found simultaneously by different people. Once a solution is found, further bottlenecks may appear elsewhere. With components connected in a seamless web, a change to one component may affect others. For instance, improvements in the efficiency of electricity generation may in turn require changes to electric motors. Or the expanding complexity of a system may require innovative new types of organizations, such as holding companies to oversee construction, management, and financing of entire electric power systems.

Another important concept in the system perspective is "momentum." Established systems
become the repository of vested interests, established modes of practice, and large bureaucracies. This renders them difficult to change or to stop. Even if no longer functioning in the most effective manner, a system with high momentum may resist change. For example, direct current electric power systems continued in use long after alternating current systems proved to be superior.\textsuperscript{36} Alternatively, a system with high momentum may facilitate the launch of new systems that utilize the same resources. The launch of the Strategic Defense Initiative in the U.S. was helped by the fact that it built on the pre-existing system for ballistic missiles.\textsuperscript{37}

Thus the system perspective provides a holistic understanding of large technical system development. Whereas conventional intellectual frameworks dissect reality, Hughes emphasizes how the pieces connect. Large systems are a seamless web of heterogeneous elements, and no study that first eliminates heterogeneity can reveal the interconnections.\textsuperscript{38}

Like other perspectives, the system perspective suffers from some weaknesses. The single greatest criticism may be that it attempts too much. The system perspective touches on economics, history, politics, sociology, engineering, and more. Specialized studies would arguably provide more insights into each aspect of systems. Process models may better describe the interactions of multiple parties in a system; organizational theory might cast more light on holding companies; sociology may offer more insights into technological momentum, and so on.
Yet such a criticism misses Hughes' most important contribution. Hughes' allows for a holistic understanding of development in its entirety rather than a highly-refined analysis of some aspect of it. His patterns are remarkable for the breadth of their synthesis rather than for the refinement of their concepts.

Despite his focus on practicing system developers, Hughes does not offer explicit practical techniques. His contribution to practice is to assist understanding, helping practitioners to "grasp the seamless web." Hughes dispels the illusion that specialization leads to effective practice, and instead opens the practitioner's eyes to heterogeneity and interconnection. Engineers, managers, or financiers might profit from the recognition that effective practice crosses conceptual and professional boundaries.

For the researcher, however, the system perspective may not open new areas for investigation. Additional work might further confirm the notion of heterogeneity and the seamless web, or it might uncover additional instances of interconnection. However, further research into concepts like reverse salients and momentum would require inquiry using the reductionist perspective of the specialized social scientist. Once such isolated insights are refined, they might be added to a heterogeneous analytical "tool set" with which to perform more holistic historical accounts or to inform practice. Table 2-4 lists the main points in the system perspective.

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### Table 2-4: System Perspective

| Main Concepts | Heterogeneity in a seamless web
|              | System has a unitary goal
|              | Phases in development
|              | Reverse salients and momentum
| Weakness     | Theoretical constructs less deeply developed
| Practical Technique | Insight into heterogeneity and interconnection |
The Institutional Perspective

The final intellectual framework reviewed here is the institutional perspective. Somewhat more attention is devoted to this perspective than the others, because the model proposed in this study itself employs the institutional perspective. In what follows, we consider the definition of institutions, the broad literature on "new institutionalism," and the relevant literature on large technical system development.

Contrary to the view of development as a choice or as a process in which outcomes result from the free and intentional interactions of one or more agents, the institutionalist view focuses on the structures that condition choices and processes. Institutions structure interactions in social, political, and economic affairs. They may affect outcomes in a variety of ways, including by distributing power differently among groups, by providing incentives for some actions and not others, by defining actors definition of self-interest, and by giving greater predictability to events. Institutions constitute the background structure within which human action takes place.

When outcomes reflect this institutional background more than the decisions of actors in a process, then it is appropriate to explain the outcomes with reference to institutions. However, institutional explanations are not perfectly efficient: institutions do not fully explain an outcome, but only create conditions that favored an outcome: "... institutions constrain and refract politics but they are never the sole 'cause' of outcomes." Actors make their own decisions, but within an institutionally-structured context.
The institutional perspective may contradict common-sense understandings of the primacy of free action in human affairs, but it does not contradict widely accepted views of human nature. In the institutional perspective, individuals are pragmatic. They can discern what "works" and what is unfeasible and adapt their actions accordingly. It is this pragmatism at the level of the individual that signals the operation of institutions at the level of the process: pragmatic individuals adapt to what "works" and what does not, and in so doing they may unwittingly follow a path prescribed by background structures. Ultimately, the outcomes of a series of pragmatic adaptations may reflect institutions more than the free choices of actors.

Institutions often work invisibly. Pragmatic individuals may remain unaware of the larger forces influencing their adaptations. They may even deny that they operate within any constraints at all. Because of this invisibility and denial, many institutional writers have emphasized that actors must first learn to recognize institutions in order to attain true freedom of action. The comments of sociologist Emile Durkheim at the beginning of the century express this well:

"It is difficult for man to have to renounce the unlimited power over the social order that for so long he ascribed to himself. Moreover it appears to him that, if collective forms [institutions] really exist, he is necessarily condemned to be subjected to them without being able to modify them. This is what inclines him to deny their existence. Repeated experiences have in vain attempted to teach him that this all-powerfulness, the illusion of which he so willingly entertains, has always been for him a cause of weakness; that his dominion over things only really began when he recognised that they have a nature of their own, and when he resigned himself to learning from them what they are.""41

Institutions have recently attracted intense theoretical interest. In an intellectual movement

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known as the "new institutionalism," researchers in the fields of political science, economics, and sociology have illuminated previously unrecognized ways in which institutions affect outcomes. Most relevant to the study of large technical system development are works in political science.\footnote{42}

Two broad institutional schools are discernible in the political science literature: rational choice institutionalism and historical institutionalism.\footnote{43} These refer to large bodies of literature and can only be accorded the briefest sketch here.

The rational choice school within the institutional perspective developed in studies of legislative behavior in the U.S. Congress. Writers there sought to explain how stable majorities could form in Congress, despite the logical deduction that self-interested legislators would find it in their rational self interest to quickly form a new majority to overturn a bill shortly after its passage.\footnote{44} An explanation was found in the institutions that structure Congressional activity: rules of procedure and committee structures conditioned the choices available to legislators, limiting each one's choices and rendering their colleagues' actions more predictable. The institutionally-constrained choice set made it rational for each legislator to behave in manner compatible with stable lawmaking.

The broader rational choice institutional model that grew from this rests on a number of assumptions. These include: that actors engage in the strategic pursuit of self-interest; that interests are given and do not require explanation; and that institutions define a strategic

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context that constrain self-interested behavior. Many of these assumptions are shared with the rational actor model above. These assumptions can impart a disconcerting style of explanation on events, as rationally-acting legislators are portrayed as ruthlessly pursuing their self-interest with complete disregard for moral constraint or the common good. However, such mechanical assumptions do allow events to be modeled very concisely. Institutional models achieve theoretical purity at some expense of detail and complexity.

The second kind of new institutionalism examined here is historical institutionalism. Historical institutionalism also presupposes a world structured by institutions in which actors define strategies and pursue their interests. However, their actions in the present take place in the context of institutional structures inherited from the past. Although those structures are themselves the product of earlier human agency, over time they become enduring features of the external structure within which later agents act. Studies in historical institutionalism explain outcomes in the present with reference to the influence of inherited structures.

Studies here have explained different outcomes in the political processes of health policy-making or labor activism by noting how actors derived differential benefits and strategic advantages from their institutional context. Institutions examined here include such things as veto points in political arenas, where some actors exercise expanded influence over policy-making, or the differential power of actors in the legislature and the judiciary. By comparing similar political processes in different countries, historical institutionalists have shown how national-level institutions like state structure or the organization of interests influence

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outcomes.

Historical institutionalism differs from rational choice institutionalism in a number of respects. Historical institutions affect the distribution of power, giving some actors greater leverage in political conflict. Actors' preferences are not taken as simply given, but can themselves be the product of institutions; collective interests partially reflect the aggregation of individual members' interests, but they are also shaped by institutions of collective action. The historical institutionalists also employ a more inductive approach, interpreting empirical observations rather than relying on universal assumptions of human rationality. Works here record the richness and complexity of the social word, at some cost of reduced theoretical purity.

Within the institutional literature on large technical systems, there exist works that build on both the rational choice and historical approach to institutionalism. Despite these differences in theoretical approach, however, writers on large technical systems have focused on similar institutions, the constitutionally-defined organization of the U.S. federal government.

In *New Weapons Old Politics* Thomas McNaugher explains the Department of Defense's record of inefficient system development as the result of pressures imposed by U.S. political institutions. He notes that the requirements for political oversight by Congress and for conformance with standard operating procedures by the military undermine effect technology development. In his explanation of defense procurement, McNaugher adopts an historical approach to illuminate the historical origins of procurement practices: "The way to bring these
trends and continuities to light is to trace the path by which the process got to where it is."47

His study examines the history of defense procurement in order to identify the institutions that structure today's processes.

A similar work employing the rational choice approach is Linda Cohen and Roger Noll's *The Technology Pork Barrel*. There, Cohen and Noll offer an institutional analysis for the outcomes of federal commercial technology development programs.48 These authors argue that although each program they examine is historically unique, a common institutional context imposes a similar pattern of development on each of them. The institutionally-defined interests of the different parties and the process by which policy is made ensure that most programs will have the same outcomes. Development is explained not so much by choice or by process as by the institutional context.

Cohen and Noll's work illustrates well the strengths and weaknesses of the institutional approach. From their study of six commercial technology programs, they conclude:

"American political institutions introduce predictable, systematic biases into R&D programs so that, on balance, government projects will be susceptible to performance underruns and cost overruns."49 According to these authors the U.S. political system rewards behavior that undermines technology development practice.

Cohen and Noll examine institutions in terms of the incentives that affect the behavior of Congress, public administrators, and industry. Incentives acting on Congress introduce

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distributional and temporal biases to development. Congressional budget-makers push for excessive funding to satisfy distributional concerns among their constituents, and they push for non-termination of funding to avoid the shock of funding cuts on constituents.

Such "pork barrel" behavior does not reflect free choice of corrupt politicians. Rather, this behavior is required of any rational member of Congress hoping to continue serving in that institution. As long as the institutional incentives reward pork barrel spending and punish fiscal responsibility, then such spending will occur regardless of the individual in office. For this reason all programs tend to be over-funded.

Institutional incentives affect other participants in development as well. Incentives acting on agencies bias behavior towards exaggeration of benefits and continuity with existing missions. Agencies face incentives to develop new means to do essentially the same task. Finally, industry's biases reflect the competitive market institutions within which they operate. Their political support is subject to the market imperative that none of their competitors should receive disproportionate benefits from a public program designed to assist all firms.

Taken together, these institutional incentives and constraints impose a predictable pattern on development programs. Federally-funded programs typically exhibit performance underruns because of the original exaggeration of benefits by their proponents. They typically exhibit cost overruns once underway because they create self-interested constituencies that influence Congressional decision-making about program funding. The persistence of institutional
incentives causes different programs to experience similar outcomes.

Thus institutional models penetrate the illusion of human agency to reveal the structures shaping development. Although program participants may be surprised that development moves in a direction different from that intended, the observer who is aware of institutional effects may recognize a familiar pattern of influence.

Despite its neglect of human agency, the institutional model offers many practical techniques for use by practitioners. These techniques involve recognizing institutions, designing institutions, and avoiding policies that conflict with institutions.

According to some writers, the first step toward confronting institutional effects is to free oneself from false beliefs about individual action and recognize institutions. Thus a report by the U.S. General Accounting Office on the problems of weapons system development urged participants to stop blaming individuals and to recognize the perverse incentives acting on all of them. By recognizing the larger forces at work, participants in system development would make an important first step toward solving their problems.

Another practical method deriving from this model is institutional design. If institutions affect development, then practitioners should design institutions well-suited to policies. This is a meta-level technique, for it involves changing the institutional rules of the game rather than playing the game more effectively. Cohen and Noll, for instance, suggest creating a federal

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agency and two Congressional committees to assume responsibility for early commercial technology development. This would better align political incentives with the logic of technology development. Sapolsky identifies a strategy for institutional design at the project level. When oversight of participants in system development is not feasible, a structure that places participants in competitive relationships makes each of them the overseer of the other. The competition-inducing structures achieve discipline without surveillance and control. (This same strategy underlies market institutions and anti-trust law as well.)

Finally, a third set of practical insights concerns policies rather than institutions. Given that institutions may not allow for modification (especially political institutions defined by constitutional law), some authors suggest avoiding policies that do not fit existing institutions. For example, critics of a U.S. industrial policy note that the U.S. simply cannot implement a Japanese-style industrial policy. Japanese political institutions include a strong bureaucracy capable of taking decisive actions, including eliminating weak industries. The U.S., with its more open institutions, cannot implement such policies. Any attempt to pursue such a policy in U.S. institutions is likely to result in wasteful spending. The U.S., therefore, should not engage in industrial policy. Cohen and Noll also recommend avoiding technology policies altogether.

With its positive and practical attributes duly noted, some weaknesses in the institutional model can also be cited. First, the process of policy-formulation leading to program launch receives little attention from Cohen and Noll. Their model only applies once a proposal has been

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made. Thus they have little to say about the historical origins of proposals for new technologies and consider all proposals equally valid until later events prove them wrong. This ahistorical reductionism may go too far. For example, the fact that NASA needed the Space Shuttle in order to remain robust after completing the Apollo program should not be ignored; great compromises were accepted in the program as long as it (and perhaps NASA itself) was not killed outright. The outcome of the Shuttle program cannot be explained without understanding its historical origins.

Second, Cohen and Noll also pay scant attention to the socially-constructed nature of technology. Treating the technology design as an independent variable, they consider it as a factor outside of the social process. They fail to acknowledge that the design of technologies, like the design of proposals, is a product of a political process. Since Cohen and Noll admit that designs affect outcomes, their inattention to the process by which those designs come into being excludes important variables from their model.

A third critique is that the institutions examined are too general. Although all policies pass through the institutions of Congress and the Presidency, sectors as different as transport, space, and communications all have unique sectoral institutions that influence outcomes. The history of NASA, its modes of operation, and its established sub-contractors are quite different from those of the Federal Aviation Administration. The policies for a Space Shuttle and a Supersonic Transport are subject to quite different institutional imperatives and constraints at the sectoral level, despite the broad similarities of larger institutions. Cohen and Noll's model
is too general to capture such influences.

Thus the institutional model provides the fourth theory of large technical system development. Table 2-5 presents the main points of this model.

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<th><strong>Main Concepts</strong></th>
<th>Structural incentives &amp; constraints</th>
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<td></td>
<td>Common context makes different programs similar</td>
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<td></td>
<td>Repeated cost overruns &amp; performance underruns</td>
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<td><strong>Weakness</strong></td>
<td>Ignores policy formulation</td>
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<td>Technology treated as a given</td>
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<td>No distinction made between diverse sectors</td>
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<td><strong>Practical Technique</strong></td>
<td>Recognition of institutions</td>
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<td></td>
<td>Design of institutions</td>
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<td>Avoid policies that poorly fit institutions</td>
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</table>
Gaps in the Literature

These works provide an overview of the literature on large technical system development. There is much to be learned from these models; each has strengths and each suffers from weaknesses. Each highlights some aspects of development while neglecting others.

Do gaps exist in this literature where research can make a contribution? We argue that they do. There is room for contribution to institutional theory at the level of sectors.

The institutional theories examined here consider national-level institutions. Cohen and Noll focus their attention on the structures of the federal government, offering a model that applies to all policies in a nation. This implies that the institutionally-defined capacities of the state are constant across all sectors of the economy or the polity. Their model is extremely broad. As a result, their approach yields rather broad-brush insights: U.S. institutions require (overly) broad coalitions for policy-making and federal spending tends to continue even when unjustified. Although valid, their insights are very general.

Similarly, although McNaugher focuses on one sector (defense) his conclusions also concern national institutions. U.S. institutions contradict the logic of technology development. He does not consider whether there could be differences between sectors in their ability to develop technology.

What this literature neglects is institutions whose influence is narrower than an entire country.
Development processes are also structured by institutions particular to sectors, such as aerospace, health, or transportation. Sectoral institutions may also influence the policy process. If such sectors can be identified and their effects understood, then additional insights into factors affecting policy might be gained.

Where national institutions operate horizontally, sectoral institutions operate vertically. National institutions are at one level of the government (the national level), and they affect all policies across all areas. Sectoral institutions are vertical: they affect policies within a functionally-defined sector of society, but they may include institutions at the national, state, and local levels. They can not only affect policy-formulation at the national level, but implementation at the state and local level as well.

A few institutional authors have considered sectoral institutions, however, not in a manner that relates to large technical system development. Alan Cawson has examined sectoral institutions from the perspective of corporatism, examining how collective actors mediate interests of organizations within a particular sector. His attention, however, is on the definition of collective interests within a sector, rather than on how sectoral institutions condition large technical system development in particular. Herbert Kitschelt examines the relationship between industrial sectors, technology, and institutions. However, he focuses on the interplay of national institutions and sectoral technology.

This study proposed a model of sectoral institutions for large technical system development.

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The model presented in the following chapter offers concepts with which to understand sectoral institutions and to explain large system development.
Chapter 3

THE MODEL OF SECTORAL INSTITUTIONS and

RESEARCH DESIGN

This chapter presents the theoretical insights about large technical systems derived from this study of Intelligent Transportation Systems (ITS). Building on the materials reviewed above, it attempts to make a further contribution to knowledge of large technical system development. The chapter also presents the research design used in the study, the comparative case study method.

Most of what follows is the model of "sectoral institutions." Like some of the literature just reviewed, this work uses the disciplinary perspectives of political science and sociology. Unlike other approaches, however, this model does not focus on constitutionally-defined political institutions, such as the division of power between legislative and executive branches of government. Rather, it works at a lower level of analysis, focusing on the historically-inherited structures unique to a particular policy sector.

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By presenting the final theory in advance of the empirical data from which it came, this chapter reverses the logical order of empirical inquiry. The model of sectoral institutions arose out of the empirical investigations that preceded them. However, since the concepts in this chapter inform the case histories that follow, it is appropriate to present them first.
A Comment on Models

This chapter presents a model. In order to clarify the goals of this research we here offer a comment on models. A model is an abstract representation of the world that can allow for understanding, explanation, prediction, and intervention.

A model can be more or less abstract depending on the methods of the model-builder and the purposes it is to serve. Examples of the two polar extremes of abstraction are the mathematical model of the economist and the story-telling model of the narrative historian. The former may be impressive in its predictive power, but bear only limited relevance to any particular case. The latter may say much about a particular case, but offer little with which to predict into the future.

The model offered here attempts to occupy a middle ground. Although it does not allow for mathematical calculation or computer simulation, it is sufficiently abstract for broad application.

This model is intended to support four uses: understanding, explanation, prediction, and intervention. The concepts and relationships in this model facilitate understanding by identifying the significant facts in large technical system development. They define the objects and relationships for an observer to perceive "out there." The model also explains past outcomes by relating earlier events to later outcomes. It allows for some prediction of future outcomes through deduction from current events. Finally, the model allows for intervention.
by identifying causal factors that can be manipulated to influence outcomes.

In allowing for prediction and intervention, the model attempts more than many models in political science and sociology. This reflects the commitment of the author to knowledge that can inform practice -- that is, knowledge that not only facilitates interpretation of the world but offers tools with which to change it. However, like any abstract theory the model offered here must be regarded with a degree of skepticism or "irony," for its simplicity is achieved by exclusion and reduction, and that reduction entails loss.58 Hopefully, the reader will find the loss of detail compensated by the gain in applicability.
Model of Sectoral Institutions

In this section we briefly sketch the model. Later sections then present it in detail.

What follows is a model of large technical system development based on the concept of "sectoral institutions." The concept of a sectoral institution is so essential that it is used to name the entire model. However, it is just one of the four parts. These parts are:

1. technical vision,
2. sectoral institutions,
3. the development process, and
4. outcomes of development.

Development begins with a technical vision of a system. This is a vision of the system as it will someday exist, consisting of the components, the linkages between them, and the overall functions the system will perform. This technical vision is to be realized in a process consisting of various stages of development. As the vision advances toward reality, development passes through different stages which involve distinctive tasks and impose distinctive resource requirements.

By "unpacking" a system vision, the associated resource requirements can be recognized. These resource requirements fall in three broad categories: expertise, authority, and funding. In order to engineer the system, developers must assemble expertise in the various technologies and in system integration. In order to test and deploy the system, developers need the

Chapter 3: Model of Sectoral Institutions
authority over the relevant domains of activity. In order to pay for these activities, developers need funding. The realization of a technical vision requires all these resources.

The second part of the model -- and the part that gives it its name -- is sectoral institutions. Sectoral institutions organize the resources needed for development. They influence what resources exist, who controls them, and their temporal availability. Each category of resource is organized by a sectoral institution: the division of labor defines the kind of expertise that exists and its distribution among groups; governance structures allocate authority among groups and define hierarchies among them; frameworks for funding define monetary resources existing for particular uses and controlled by defined groups. Thus sectoral institutions define both what resources are available and the groups that control those resources.

Thus, on the one hand, there are system developers seeking resources in pursuit of a technical vision; on the other hand, there are the institutionally-organized resources and the groups that control them.

These two come together in the third part of the model, the development process. Developers seek to assemble resources by assembling coalitions. They seek to assemble a coalition of all the groups that control the needed expertise, authority, and funding. Some groups may willingly join the coalition. Others may have to be induced by making changes to the development program or to the design of the envisioned system. Some groups may refuse to join altogether, requiring developers to modify their vision or to abandon development.

Chapter 3: Model of Sectoral Institutions
altogether. When resources do not exist, they have to be created, often by the creation of new organizations.

Finally, the outcomes of development manifest themselves in three products: the design of the technology, the design of the development program, and the design of new organizations (or redesign of existing ones.) ("Design" refers to the outcomes as they exist and contrasts with "vision," which refers to ideal forms.) These outcomes represent the technical vision as modified by the coalition-building activity of the development process. Ultimately, many of them reflect the underlying sectoral institutions.

Figure 3-1 illustrates the relationship between the four parts of the model. The following sections present each one in detail.
Figure 3-1: Four-Part Model of Sectoral Institutions

1. Technical Vision
2. Sectoral Institutions
3. The Development Process
4. Outcomes of Development
Part 1: The Technical Vision

The starting point of this model is the technical vision of a system. This is the vision of interconnected technical and organizational components that together perform functions. Since it is a vision, it is an idealized version of the system. It is a state of affairs that is imagined but does not exist except in the minds of an individual or group. Figure 1-1 in the first chapter presents the vision of ITS; similar pictures can be found from the early stages of many technology development projects.

The technical vision presents a picture of the final system. However, between the present, in which the system does not exist, and the envisioned future, in which the system fully exists, lie various stages of development. The technical vision not only represents the linkage of components, it also represents development over time. Thus the technical vision can be analyzed in two dimensions:

1. the system dimension, and
2. the development dimension.

The *system dimension* refers to the interconnection of components into a system. Analysis of the technical vision in this dimension divides the technical vision into its components. In the case of ITS, the components to be joined into a system were vehicles, roads, and communications.

The *development dimension* refers to the stages of development a system must traverse over.
time. In different stages of development different types of knowledge is pursued through
different tasks. That knowledge might be technical in nature (Does a component work? Can
multiple components function when connected in a system?). Or it might be functional,
organizational, or financial (Does it have benefits? Can it be operated? Can it be paid for?)
Different technical visions might imply somewhat different developmental stages. For
example, we argue below that ITS development falls into four stages (research, technical field
test, operational test, and deployment.) The development dimension represents the vision in
time as it develops through successive stages. Although this development may not be linear --
it may return from a field test back to research, for example -- ultimately system development
does traverse different stages.59

The combination of these two dimensions yields a matrix. This technical vision matrix has a
cell for each component of the system (system dimension) at each stage of development
(development dimension). The matrix allows the analyst to make sense of the technical vision,
both in terms of the components to be connected and in terms of the evolution it will undergo
from vision to reality. Figure 3-2 shows a schematic of such a matrix. Its three columns and
four rows correspond to the ITS technical vision; for a different technical vision the number
of columns and rows could be different.

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**Figure 3-2:**
*Technical Vision Matrix*

1. **SYSTEM DIMENSION**

   Components of the System
   (e.g. vehicles-roads-communications)

2. **DEVELOPMENT DIMENSION**

   Stages of Development
   (e.g. experiment, technical field test, operational test, and deployment)
This decomposition of the technical vision into a matrix is a first step toward identifying the resources needed for development. Three kinds of resource requirements can be recognized in the technical vision. These are:

1. expertise,
2. authority, and
3. funding.

First, each cell of the matrix defines some expertise. To conduct experiments on vehicle technology, obviously, expertise in vehicle technology is required. The same holds for any system component. Although the need for expertise is most obvious at the earlier stages in which technology research and testing figures prominently, it is required throughout. The operation and maintenance of a system requires both technical expertise in the components and expertise in how a transportation organization functions. To realize the technical vision, expertise in all components in all stages of development must be assembled.

Second, authority is needed to develop technology. This is more obvious in the later stages of development, such as a field test or a deployment. If a field test is going to take place in a particular geographic location, then those with authority over that domain must support the test. Even to engage in early research and development requires the support of individuals or groups with authority over research. Thus the technical vision touches on domains governed by groups with authority, and the support of those authorities will be required for development to succeed. In ITS development, for example, the need for large scale field tests on road

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networks meant that local transportation authorities would have to support development.

Third, development requires funds. This resource corresponds more to the rows of the matrix -- the different stages of development -- than to individual cells. The funding requirements vary with the stage of development. For most technologies early research is less expensive than later field tests, and field tests are less expensive than fully operational systems. In ITS development early research cost much less than city-wide field tests. ITS developers had to acquire the funding needed in each stage of field test.

In summary, the technical vision defines a matrix in two dimensions, system and development. Realization of that vision requires assembling all the resources implied by the different cells and rows. System development requires expertise, both in the component technologies and in the operating environments; it requires authority over the jurisdictions affected by development; and it requires funds to pay for the different stages. (The reader who finds the exposition here too abstract will find greater empirical content in the next chapter, where these concepts are applied to ITS.)
Part 2: Sectoral Institutions

The second part of this model is sectoral institutions. If the technical vision is an idea about a possible future, sectoral institutions are the stuff of the existing reality. They are the enduring structure within which and through which activities in a sector occur. These social structures constrain and channel the activity of development, sometimes facilitating and sometimes hindering the processes that unfold within them.

Broadly conceived, a sector is a set of organizations united by a common functional activity. That function may be the construction of roads, the production of automobiles, or the provision of communication services, or more. Within a sector multiple organizations may operate, either cooperatively or competitively. These organizations may be public agencies or they may be private corporations. What they have in common is their participation in a broad functional activity.

A sector is similar but broader than a large technical system. A sector incorporates more organizations, more technologies, and more functions than any one large technical system; a sector may be the historical residue of many different large technical systems. For example, within the U.S. road transport sector are organizations operating technology to perform functions related to road construction, vehicle safety, and more. Each of them may participate in functionally specific activities relating to their particular mission, and these many related functions together comprise a sector.
Within a sector, over-arching structures exist that apply to many organizations. These are sectoral institutions. Sectoral institutions are at the appropriate level of analysis for large technical systems, because they structure the inter-organizational and public-private relationships typical of large technical systems. Sectoral institutions are at a lower level of analysis than political institutions, which apply to policy-making in all sectors. They are at a higher level of analysis than the internal structures of individual organizations. They apply to multi-organizational processes contained within one or a few functional domains (such as the development process for the ITS vehicle-roadside-communication system.)

Three kinds of sectoral institutions organize the resources needed for large technical system development. They are:

1. the division of labor (organization of expertise),
2. governance structures (the organization of authority), and
3. frameworks for funding (the organization of funding).

The division of labor organizes expertise in a sector. Within a sector expertise exists for both technologies (e.g. electronics, traffic management) and for developmental activities (e.g. research, planning, operation) and is distributed among different organizations. In the U.S. transportation sector in the 1980s, for example, expertise in vehicle electronics and in mobile communications resided in different firms (General Motors and Motorola), whereas in Germany that expertise could be found within a single firm (Siemens). Differences in the division of labor mean that the development of similar systems in different countries requires...
participation by different organizations.

*Governance structures* organize authority in a sector. Governance structures are the set of public agencies and private corporations that exercise authority over different domains within a sector. In the U.S. road transportation sector, for instance, three federal agencies exercise authority: the Federal Highway Administration (FHWA), with authority for road planning and traffic; the National Highway Traffic and Safety Administration (NHTSA), with authority for safety; and the Federal Transit Agency (FTA), with authority for transit. Private firms also exercise authority over their domains, with most authority for automobiles and communications lying with private firms. The organization of authority also defines hierarchical relationships. For example, in the 1980s the national-level FHWA exercised significant control over state-level transportation agencies by its ability to restrict the use of federal funds to certain categories of expenditures.

Different countries may have different governance structures in functionally similar sectors. For example, in Japan two national agencies (the Ministry of Construction and the National Police Agency) share authority for traffic operations, whereas in the U.S. the FHWA is the sole federal agency with such responsibility. Differences in governance structures mean that the development of similar systems affecting similar domains in different countries requires participation by different organizations with authority over those domains.

The third sectoral institution is *frameworks for funding*, which organize financial resources in a

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sector. A framework for funding is a legal or budgetary mechanism by which funds can be allocated for activities. A framework for funding can support system development, providing the funds needed for experiments, field tests, etc. Some frameworks for funding are the internal budgets of individual agencies. For example, MITI in Japan funded ITS development largely through its own internal budget. Others are stand-alone legal mechanisms to unite independent parties. For example, the EUREKA framework in Europe provided funding for consortia of private firms to collaborate among themselves.

Just as the social division of labor and governance structures define sets of actors, so do frameworks for funding. They are controlled by sets of actors with the power to decide the uses to which resources will be applied. Those actors may include interest groups, government bodies, or political leaders. Since system development is dependent on the resources available from funding frameworks, it is dependent on the support of these actors. It is here that political power is most manifest, for power over program funding is the most direct lever for control over development.

Each of these three sectoral institutions defines a set of actors with resources needed for development. Development requires assembling the sets of actors with the resources needed for development. Table 3-1 summarizes these definitions.
<table>
<thead>
<tr>
<th>1. Division of Labor</th>
<th>Distribution of expertise among actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Governance Structures</td>
<td>Distribution of authority among actors</td>
</tr>
<tr>
<td>3. Frameworks for Funding</td>
<td>Define sets of actors with control over resources</td>
</tr>
</tbody>
</table>
Part 3: The Development Process

The two previous sections defined the starting conditions of the model of sectoral institutions. On the one hand is the technical vision with its associated requirements for expertise, authority, and funding. On the other hand are the sectoral institutions that define the existing organization of expertise, authority, and funding. These come together in the development process.

The participants in the development process are not "visions" nor "institutions" but individuals and the organizations that correspond to them. These define four sets of actors. The first set of actors, corresponding to the technical vision, are the entrepreneurs advocating development. These entrepreneur-advocates of large technical systems are usually technologists, but may include managers, public administrators, or political leaders. They possess a vision and must assemble the resources that the vision requires.

Sectoral institutions define the other three groups. Groups with expertise defined by the social division of labor include research and development units within agencies, corporations, and universities. Groups with positions of authority in the governance structure include the policy-making leadership of agencies and corporations. Finally, groups with control over frameworks for funding include elected officials, industry leaders, and interest groups.

The development process unfolds as two activities. The first of these is coalition-building. Entrepreneurs build a coalition with those actors controlling the resources needed by the
technical vision.

Coalition-building can be illustrated here with reference to ITS (although it applies to large technical systems generally.) The technical vision of ITS defined a matrix of three column (the vehicle, road, communication components in the system) and four rows (the four stages of development.) ITS advocates had to identify existing organizations with the expertise, authority, and funding for these cells and had to enlist them into a coalition supporting ITS development. In assembling the resources required by the technical vision, ITS advocates enlisted groups with expertise (e.g. from electronics firms), with authority (e.g. the Administrator of the FHWA), and with control over funding (e.g. key Congressmen and highway interest groups). ITS development unfolded as a process of building coalitions with these and other groups.

The second activity in the development process is resource creation. In some instances, resources may be lacking altogether. Where no resources exist corresponding to some need of the technical vision, then advocates must either create those resources or seek to adapt existing institutions to the needs of development. For example, the European transport sector lacked any institution with authority for pan-European infrastructure development. Yet the ITS vision required such an authority. As part of development ITS advocates attempted to design a new organization from scratch (called "ERTICO") to coordinate the many actors that shared this authority.
Coalition-building operates largely at the level of interests. Coalition members sought because of their expertise, authority, or their control over funding bring their organizational interests to the development process. Effective coalition-building requires, at minimum, that no actor's interests suffer from development. What is more likely is that actors will seek to actively reap benefits from a development program in which they participate. Thus the development process is rightfully conceived as a politicized activity in which actions are guided (or at least constrained) by interests. Large technical system development is, in part, a political process.

Coalition-building and resource creation are not once-and-for-all activities but continue throughout development. As development proceeds through different stages (moving down the rows of the technical vision matrix) the resources needed for development change. As a result, new actors may be needed while previously active coalition members may drop out. Where expertise, authority, or funding is lacking, new institutions may have to be designed. System advocates are busy building coalitions throughout the development process.

Thus the development process, the third part of the model, unfolds as an activity of coalition-building and resource creation. The interaction between technology and social context unfolds as a negotiation process between advocates of a technical vision and institutionally-defined sets of actors with expertise, authority, and funding. Sectoral institutions influence development by defining the existing actors corresponding to the requirements of the technical vision.

Table 3-2 summarizes these definitions.
Table 3-2: 
Activities in the Development Process

<table>
<thead>
<tr>
<th>1. Coalition Building</th>
<th>2. Resource Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assemble actors with needed expertise, authority, &amp; funding</td>
<td>Compensate for gaps in expertise, authority, &amp; funding</td>
</tr>
</tbody>
</table>
Part 4: Outcomes of Development

In the process of development the technical vision evolves. In building coalitions different aspects of the large technical system become the basis of negotiation. Changes in program design, technology design, and organization design are traded for actors' participation in the coalition. The final outcomes of development reflect both the original technical vision and the interests of institutionally-defined actors.

This model identifies three outcomes of development. These are:

1. technology design,

2. program design, and

3. organization design.

Technology design refers to the functionality and degree of integration in a large technical system. Technology design may vary in the number of functions included in the system. Some ITS development programs produced systems offering just a few functions, while others produced designs with literally hundreds of functions. Some stayed focused on their original technical vision and others evolved in unforeseen directions. The degree of integration also may vary. Some ITS programs defined a comprehensive system architecture to integrate the system, while others produced potentially incompatible systems. Again, these outcomes reflected sectoral institutions.

Program design refers to the size and pattern of spending and to the relative emphasis given to
different stages of development. Among ITS programs, for example, some spent hundreds of millions of dollars and others spent just millions. Some focused on a few activities and others pursued a broad array of experiments and field tests. Some systems progressed all the way to deployment, while others stalled in early experiments or field tests. These outcomes reflected the influence of sectoral institutions.

Finally, organization design refers to the creation of new organizations or the modification of existing organizations. Organizations may be designed or redesigned in order to compensate for missing resources. Organization design reflects gaps in the sectoral institutions, where a lack of resources had to be corrected.

As mentioned earlier, the term “design” refers to the form of the resulting program, technology, and organization, rather than to the initial ideal vision. Table 3-3 summarizes the three types of outcomes.
Table 3-3: Outcomes of Development

<table>
<thead>
<tr>
<th>1. Program Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns of Spending</td>
</tr>
<tr>
<td>Emphasis on Different Stages of Development</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Technology Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functions included in system</td>
</tr>
<tr>
<td>Integration in a system architecture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Organizational Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creation of new resources</td>
</tr>
</tbody>
</table>

These outcomes manifest the influence of sectoral institutions. Outcomes are the products of negotiations between advocates and other actors with needed resources. Entrepreneurs assemble coalitions by trading participation for modifications to the design of program, technology, and organization.

In summary, this study proposes a four-part model of large technical system development. Development begins with two starting conditions, the technical vision and sectoral institutions. These interact in development process, manifesting themselves in the activity of coalition-building and institutional design. Interests and expertise interact to shape the outcomes contained in the program, system, and organization design. Figure 3-3 depicts this model with all its subsidiary concepts.

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Figure 3-3: Full Model of Sectoral Institutions

1. Technical Vision
   - Matrix in 2 dimensions:
     1. system components
     2. stages of development
   - Resource Needs:
     expertise
     authority
     funding

2. Sectoral Institutions
   - Division of labor (expertise)
   - Governance structure (authority)
   - Frameworks for funding (funding)

3. Development Process
   - coalition building
   - resource creation

4. Outcomes of Development
   - program design
   - technology design
   - organization design
Summary

As presented so far, this model can be used for understanding and explanation. The model's concepts define the objects and relationships in development; armed with these concepts an observer can understand what is occurring. The model explains outcomes in terms of the coalition-building and resource creation activities of system advocates as they assemble resources.

The model can also be used for prediction and for intervention. These topics are addressed in the final chapter.

The reader will notice that this model attributes little importance to the technology itself. Outcomes are explained with reference to social factors like sectoral institutions and coalition-building. However, this approach does not exclude consideration of technical functionality. Rather, technical functionality figures in development when some coalition member makes it their concern. Some actors -- typically technologists responsible for research and development -- may serve as the representatives of technical functionality in the development process. Still, if no actor makes technical functionality a concern, it could be neglected. This is consistent with the experience of many development programs. As Cohen and Noll show, the history of U.S. federal technology policy includes many programs that continued long after the technology was shown to perform poorly. Thus even a technically dysfunctional system may be developed if coalitions form in support of it.

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This model also attributes little importance to rational decisions based on the benefits of the technology. Advocates of large technical systems invariably justify development costs with favorable estimates of future benefits; however, they usually lack evidence of those benefits. With no ability to evaluate a system that does not exist, benefits remain uncertain -- that is the nature of technology development. Lacking data with which to make decisions about costs and benefits, decisions about development tend to be based on speculative estimates of the future. These estimates are easily influenced by secondary considerations, such as the interests of the coalition members.

Like the models of large technical system development reviewed earlier, this one has some weaknesses and it has some practical implications. The model has two weaknesses. First, the distinction between fixed institutional structures and the fluid processes they contain can become hazy. A national constitution remains fixed for longer periods of time than does the division of labor in a sector. Since sectoral institutions are not completely outside of the fray, this model is at risk of dissolving into the process model described in Chapter 2.

Second, this model is also at risk of being subsumed into the larger political institutions model. Some sectoral institutions are closely related to political institutions. In particular, frameworks for funding are often controlled by national legislatures and manifest influences from these national institutions. Where the effects of national institutions are particularly powerful, the influence of sectoral institutions may be less noticeable. Some effects could be attributed to both types of institutions.
Like the models reviewed in Chapter 2, the sectoral institutions model also provides some practical techniques. First, the model provides tools for analyzing institutional structures in order to recognize opportunities and barriers. Second, the model suggests techniques for coalition-building. Table 3-4 summarizes the sectoral institutions model.

<table>
<thead>
<tr>
<th>Main Concepts</th>
<th>Technical Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sectoral Institutions</td>
</tr>
<tr>
<td></td>
<td>Development Process</td>
</tr>
<tr>
<td></td>
<td>Outcomes of development</td>
</tr>
<tr>
<td>Weakness</td>
<td>Risks dissolving into process or political institutions model</td>
</tr>
<tr>
<td>Practical Technique</td>
<td>Institutional analysis</td>
</tr>
<tr>
<td>(in final chapter)</td>
<td>Strategy-formation</td>
</tr>
<tr>
<td></td>
<td>Coalition-building</td>
</tr>
</tbody>
</table>

Chapter 3: Model of Sectoral Institutions
Research Design

The sectoral institutions model is the result of this study on ITS. Although presented before the ITS case histories, it is in fact the product of that empirical investigation of ITS development.

In the remaining pages of this chapter we now examine the research design and methodology. The methodology employed here was comparative case histories, a two-part method building on case history and cross-case comparison. The case history method uses sites visits, interviews, and review of documents. Through this activity the main events of a case and the relationship among those events are assembled. The activities of many different historical actors are composed into a larger picture of social activity.

In cross-case comparison the events in different cases are compared in order to better understand each one. This allows each case study to be observed from an external standpoint. Through comparison the researcher can perceive both similarity and difference. Similar concepts applicable to all case histories can be perceived, and in this way general models can be developed. Alternatively, events visible in one program may direct the researcher's attention to causal factors that remain obscure in another program. In this way comparison reveals features that would otherwise remain obscure. Thus comparison both illuminates the individual case histories and allows for generalizations applicable to other large technical systems.

Chapter 3: Model of Sectoral Institutions
This investigation examined ITS programs in three geographical locations: the U.S., Japan, and Europe. Five programs were examined, one in the U.S., one in Japan, and three in Europe (ALI-SCOUT, PROMETHEUS, and DRIVE). For each program the author interviewed key participants and exhaustively reviewed original documents. For four of the five programs the author conducted site visits (there was no site visit to Japan.)

The existence of parallel programs around the world made ITS especially well-suited for the comparative method. The programs all shared one technical vision. Yet each ITS program was conceived, launched, and executed in a different social context structured by different sectoral institutions. Comparison revealed how these differences in social context affected development. Similarities across the five programs allowed for the formulation of generalities.

The strategy for inquiry used here can be restated in the precise terminology of research. The research sought to construct general statements of causality about large technical system development. The hypothesis of the research was that two sets of explanatory variables stand in a relationship of cause and effect to a set of dependent variables. The sets of explanatory variables are "technical vision" and "sectoral institutions," and the set of dependent variables was "outcomes of development." Technical vision (defined as the envisioned system design) and sectoral institutions (defined as organization of expertise, authority, and funding in a sector) were hypothesized to affect outcomes of development (defined as technology design, program design, and organization design.)

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The experiment consisted of the observation of five programs pursuing the same technical vision in the context of five different sets of sectoral institutions. Although the data set was small (N=5), the case histories did support the hypotheses. Variations in sectoral institutions were accompanied by variations in outcomes. The hypotheses emerged strengthened, and are offered here as the sectoral institutions model of large technical system development. This model may be used for the understanding, explanation, prediction, and intervention in large technical system development.
The Case Histories

In regard to the case histories themselves, two questions might arise about their suitability for research. First, since several of the ITS programs were still far from completion, was it not too early to examine them? Our answer here is no. True, system development was nowhere complete and, therefore the analyst cannot explain programs' ultimate "success" or "failure." Nonetheless, many programs were twenty years old and offered a rich history of development. Other well-known studies of technology development have examined comparably short periods of time.62

A second concern might be that the cases were too different to allow for comparison. That was not so. The case studies were well-suited for comparative analysis because their technical visions were all nearly identical. As parallel projects pursuing the ITS technical vision, all the projects were nearly identical. Both of these methodological considerations are discussed further in the final chapter.
ITs programs around the world all shared the same technical vision of Intelligent Transportation Systems. That technical vision provided the basis for comparison across programs. This chapter analyzes the ITS technical vision.

In what follows, the technical vision is examined from two perspectives. First, using concepts from the sectoral institutions model above, the technical vision is “unpacked” into the two-dimensional matrix of system and development. This reveals the constellation of expertise, authority, and responsibility that all programs had to assemble in order to realize the ITS vision. Second, some early history of ITS development is recounted in order to explain how the same vision came to be pursued around the world.
Analysis of the ITS Technical Vision

As described in the first chapter, the common ITS vision was of 1) an information technology-based vehicle-roadside link making possible 2) system capabilities of surveillance and control in order to 3) provide individual route guidance and area-wide traffic optimization. Vehicles and roads, previously autonomous of each other, would be joined by a communications link. This integration would transform a passive road network into a traffic system in which both individual drivers and area-wide traffic controllers could make decisions based on real-time information about the state of traffic. For the driver this could help in selecting routes to a destination, while for the area-wide controller it would allow for more efficient management of traffic on the road network.

This technical vision can be analyzed in a two dimensional technical vision matrix, as discussed earlier. Figure 4-1 shows the technical vision matrix for ITS. The system dimension consists of the components of the system. The development dimension consists of the stages of development.

In the system dimension the ITS technical vision consisted of three components:

1. vehicles,
2. communications, and
3. roads.

Each column represents a component, so that each row represents the entire system at a stage in development.

Chapter 4: The Technical Vision
In the development dimension the ITS technical vision defined four stages of development:

1. research

2. technical field test

3. operational test, and

4. deployment\textsuperscript{63}
Figure 4-1:
Technical Vision Matrix for ITS

<table>
<thead>
<tr>
<th>SYSTEM DIMENSION</th>
<th>Vehicles</th>
<th>Roads</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVELOPMENT DIMENSION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Technical Field Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Operational Test</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4. Deployment</td>
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</tbody>
</table>
Unlike the system dimension, which derives directly from the technical vision, the development dimension requires some explanation. The four stages correspond to four different kinds of tasks to transform the ITS vision into a reality. Each task would reduce some kind of uncertainty.

In the research stage uncertainty about components would be reduced. Prototypes of the system components would be tested to find out whether they functioned. Examples of research were: testing mobile communications via infrared beacons or microwave transponders; developing map databases on compact disks; or developing routing algorithms on central computers. In ITS development the research stage presented the least uncertainty of all stages of development because many of the component technologies already existed and were known to function.

The research stage also imposed relatively small resource demands. Considerable expertise would be needed, but only little authority and funding. Technical expertise would be needed in vehicles, roads, and communications, but ITS required no basic research. Little jurisdictional authority would be needed, since research would be on a small scale and often in a laboratory or test site. Funding requirements would be low, at least in comparison to later stages.

The second stage of development would be technical field tests. Here attention would shift away from the functionality of single components to the functionality of an integrated system.
The goal would still be to reduce technical uncertainty by learning about functionality.

However, here the uncertainty lay in the ability of all components to perform together as a system. Technical field tests would have to be large in size, at the scale of an entire city. In the case histories below, two examples of technical field tests were CACS in Tokyo and LISB in Berlin, each of which installed an experimental system on the scale of an urban area.

Resource demand were much larger for technical field tests. Expertise would still needed as before. Authority would also be needed. To conduct a technical field test in a city, the city’s political leaders and transportation authorities would have to support it. Funding would also be needed. Considerable funding would be needed to equip hundreds of vehicles, hundreds of roadside systems, and a central computer.

The third stage of ITS development would be the operational test. With technical uncertainty reduced from the first two stages’ activities, this third stage would seek to reduce operational uncertainty. Once the technology was known to function, it would be investigated for its benefits in operation. The ability of organizations to operate the technology would also be tested. In Japan the RACS and AMTICS operational tests investigated the ability of transportation-related ministries and agencies to operate systems and to derive benefits from them.

In the third stage the need for expertise would be less than in previous stages, since most technical uncertainty would be reduced and the system design more stable. However,
jurisdictional resources would be in high demand. Operational field tests would test the ability to integrate the technical system into existing jurisdictions and so would require support from transportation policymakers. Funding requirements for operational tests were also high. However, they might decline from the previous stage, if existing technical field test system could handed over to local authorities for operation.

Finally, the fourth stage would be deployment for regular operation. With little remaining uncertainty about the technical functionality and operational benefits of ITS, this final stage would address uncertainty about the broad adoption of the technology by operating organizations. Expertise would be required in these organizations in order to operate and maintain systems. Authority and funding would also be in high demand. In order to be implemented, actors with authority over the implementation site would have to support it and funds for deployment would have to be found.

These four stages could be anticipated in advance. Although development contained much uncertainty, the resources required to reduce that uncertainty were predictable. The pattern and sequence of resource requirements derived from the technical vision.

This much was the same in all ITS programs. Each program began with a technical vision of ITS with three system components and four stages of development. To develop ITS each program had to assemble a coalition of actors with the expertise, authority, and funding relevant to all these components and all these stages of development.

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Despite their shared vision, each ITS program would unfold in a different institutional context. ITS developers in each program would have to assemble different coalitions, depending on how sectoral institutions organized expertise, authority, and funding. Each of the case histories in later chapters traces how they did this.
Origins of the ITS Vision

The ITS technical vision just described was common to programs around the globe. This section shows how this parallelism came about.

The same ITS technical vision came to inform programs around the world for two reasons. First, the technical vision was an obvious next step for road infrastructure, so technologists everywhere could have the same idea. Second, most ITS programs derived their vision from a single common project tested in the U.S. around 1970.

The ITS vision of transforming a passive network to a managed system had been realized in other networks before. With many precedents for the application of information technology to transportation networks to increase traffic efficiency, the ITS vision was an obvious next step for road transport. Train networks in the nineteenth century and road networks in the early twentieth century both used signal systems in order to increase their traffic efficiency and safety. In the 1960s and 1970s area-wide adaptive road traffic signal systems were developed and installed around the world that allowed traffic control centers to coordinate traffic signals in order to improve capacity. In the 1950s the U.S. installed a nation-wide air traffic control system linking ground-based traffic controllers to in-vehicle pilots. ITS would be a similar traffic information and control system for vehicles on roads.

Indeed, the vision of such a system was put forward as early as 1939 at the World's Fair. At its Futurama Exhibit General Motors showed a radio tower communicating with drivers in
order to manage traffic flows. With the basic ITS vision so well established, it was hardly surprising that development programs should begin around the world.

The diffusion of a common ITS vision can be traced out even more concretely, however. One early research program in the U.S. provided a reference point for activities around the world.

Between 1967 and 1971 the Federal Highway Administration (FHWA) conducted research on an ITS prototype called the Electronic Route Guidance System (ERGS). ERGS realized many of the component functions of the ITS vision. Vehicles were equipped with on-board computers that could accept a destination code from the driver, transmit it to roadside computers, and receive back routing instructions that took account of current congestion on the road network. Loop antennas were buried in the road surface to provide the communication link between the vehicle and the road. Plans were made to connect roadside computers to a central computer capable of modelling traffic on the entire network and calculating routing instructions that optimized overall traffic throughput. Figure 4-2 depicts ERGS.
Figure 4-2: Electronic Route Guidance System (ERGS)

Fig. 3. Code letters designating the destination address of the driver.

Fig. 4. Driver enters destination code.

Fig. 5. Car approaches loop.

Fig. 6. Loop triggers car transmitter.

Fig. 7. Car transmits destination to roadside unit.

Fig. 8. Roadside unit decodes destination and determines correct routing instruction.

Fig. 9. Roadside unit transmits routing to car.

Fig. 10. Routing symbol is displayed to driver.
The 1970 ERGS research corresponded to the research stage of ITS development (the first stage of development.) It tested individual system components, operating in two street intersections, but did not investigate technical issues arising from an entire system. 66

The developers who pioneered ERGS were based in the Office of Research and Development in the FHWA. This office possessed research expertise in both roads and communications -- the latter due to a recent influx of new staff from a post-moon-launch NASA. Additional expertise for the vehicle component was obtained by contracting with Philco-Ford and General Motors Delco Radio Division. 67 Thus the expertise needed for the research stage was acquired by assembling a coalition that included an FHWA research office and the automakers. As for its framework for funding, ERGS was small enough to be funded by the Office of Research and Development within FHWA. The coalition was funded as a procurement by the FHWA.

By 1969 the ITS entrepreneurs in ERGS were ready to advance to the second stage of development, that of technical field test. The envisioned ITS technical field test would involve some one hundred equipped intersections and fifty equipped vehicles through which they would investigate the technical feasibility of an area-wide system. 68 This technical field test would require expertise, authority, and funding.

ITS proponents in FHWA sought funding from the Highway Bill, the framework for funding for construction of the Interstate Highway System. ERGS proponents hoped that with the Interstate approaching completion in the 1970s and 1980s, a funding opportunity would appear for a post-

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Interstate initiative. The Highway Bill could fund not only their second-stage technical field test, but also a later program of development.

ITS proponents could not build the coalition needed for the Highway Bill, however. In 1971 the transportation appropriations committee in Congress denied the funding request for ERGS. Key actors controlling funding did not become supporters of the technical vision, and development failed.

Thus the first ITS development program never progressed beyond the first stage of research. Following ERGS the ITS development program was terminated. The ITS proponents had been unable to form the funding coalition for a technical field test.

Despite its short life, ERGS had long-term consequences. It made the ITS vision concrete for all to see, including many overseas visitors. And those that saw the research brought back the technical vision to different social contexts more supportive of technical field tests.

Towards the end of the ERGS research a team of Japanese researchers visited the U.S. to inspect the ERGS technology. Upon returning to Japan they organized a similar program, conducting research and a technical field test of a system based on ERGS. The Comprehensive Automobile Traffic Control System (CACS) used on-board and roadside computers communicating via in-road loop antennas to provide route guidance information to drivers.69 CACS marked the beginning of the Japanese ITS development program. Its

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technical vision came from ERGS.

The ERGS design was also taken up in Germany. Bosch/Blaupunkt, an electronics supplier of items like car radios and anti-lock brakes, performed ITS research from 1979 to 1982. Called ALI (Guidance and Information System), it tested the components of a vehicle-roadside route guidance and information system. ALI used on-board and roadside computers communicating via a buried antenna to transmit destinations and receive guidance instructions. Thus ITS development in Europe also began with the technical vision from ERGS.

Figure 4-3 shows the three systems that marked the start of ITS development in the U.S., Germany, and Japan. As can be seen in these technical visions, each system included the following components: in-vehicle display, loop antenna, roadside computer, and central computer.

Two later European programs, called PROMETHEUS and DRIVE, do not trace their origins directly back to ERGS. Their technical vision was nonetheless very similar. PROMETHEUS pursued a technical vision of traffic as a system based on the integration of the vehicle and the roadside. This was the same as ERGS. DRIVE began with a different vision. Its initial goal was to take information technology developed in earlier European Union programs and apply it to the transport sector. Over time, however, DRIVE adopted the vehicle-roadside system vision and thereby became comparable to the other programs.
Although ITS development in the U.S. underwent a twenty-year hiatus following ERGS, ERGS strongly influenced the later program. Indeed, the connection could not have been more direct: the same individual who as a young engineer left NASA to work on ERGS in 1968 led the ITS entrepreneurs from FHWA in 1991. Here the continuity of the FHWA research staff ensured the continuity of the technical vision. Like the Japanese and European programs, the U.S. ITS program began with the same technical vision.

Sharing the same technical vision, all five ITS programs had to assemble similar resources as they passed through similar stages of development. The resource needs imposed by this vision were the same. However, their different institutional contexts differentially affected their ability to meet those needs. The programs' outcomes reflect those differences in the institutional context.

Figure 4-4 shows a timeline of the different ITS programs around the world, beginning with the ERGS program. Later programs are examined in the following case histories on Japan, Europe, and the U.S.
Figure 4-2:
Early ITS Systems in U.S., Germany, and Japan

Figure 2a: Early Route Guidance Research and Test Projects - USA 1967-1971
(Source: Rosen et al. 1970)

Figure 4-2b: Early Route Guidance Research and Test Projects - Germany 1977-1980
(Source: Braess 1980)
**Figure 4-1:**
**Timeline of World ITS Programs**

<table>
<thead>
<tr>
<th></th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
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</thead>
<tbody>
<tr>
<td>USA</td>
<td>ERGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IVHS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EUROPE</td>
<td>ALI</td>
<td>ALI-SCOUT/LISB/EURO-SCOUT</td>
<td>PROMETHEUS</td>
<td>DRIVE</td>
<td>DRIVE II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JAPAN</td>
<td>CACS</td>
<td></td>
<td>SSVS</td>
<td>AMTICS</td>
<td>VICS</td>
<td></td>
<td></td>
<td>RACS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARTS</td>
<td>ASV</td>
<td>UTMS</td>
<td></td>
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</tbody>
</table>
Chapter 5

ITS DEVELOPMENT IN JAPAN

If ITS development first began in the U.S., it was in Japan that it initially took hold. Of all the world’s ITS programs, those of Japan showed the most consistency. Beginning in 1973 the Japanese engaged in a steady series of ITS-related research and development activities right through the mid-1990s.

This chapter recounts the history of ITS development in Japan. The next two chapters then recount the histories of the European and U.S. programs. These three empirical chapters employ the concepts of the sectoral institutions model to make sense of the parallel programs, both to identify significant events and to explain how they relate to each other. The sectoral institutions model both illuminates programs’ similarities and explains their differences. In what follows the sectoral institutions are analyzed, the development process is traced through the four stages, and the effects of institutions on the outcomes of development are identified.

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Sectoral Institutions

The ITS technical vision was analyzed in the previous chapter (see Figure 4-1.) The technical vision matrix had three columns in the system dimension, corresponding to the components (vehicle, road, communications), and four rows in the development dimension, corresponding to the four stages of development. As explained, the matrix indicated the expertise, authority, and funding needed to realize the technical vision.

This chapter examines sectoral institutions (see Table 3-1.) Whereas the technical vision defines the needed resources, sectoral institutions define the available resources. The degree of match and mismatch between what the ITS technical vision required and what Japanese sectoral institutions made available explains many aspects of the final outcomes.

In Japan, four different industry or policy sectors were relevant to ITS. Three of these corresponded to the three system components: the automotive, road transport, and communications sectors. A fourth relevant sector was the technology sector, which in Japan was centered in the Ministry of International Trade and Industry, or MITI. Within these sectors were a variety of government agencies and private firms possessing the resources needed for ITS development.

The first of these sectors, the automotive sector, included a variety of manufacturers of automobiles, trucks, and motorcycles. Throughout the 1970s, 1980s, and 1990s this sector included such well-known firms as Toyota Motor Corporation, Nissan, Honda, Mitsubishi,
Mazda, Subaru, Suzuki Motor Corporation, and others. These firms were economically strong. This sector had traditionally close ties with MITI.

The second sector, road transport, consisted mostly of government agencies. The two most important of these were the Ministry of Construction (MOC) and the National Police Agency (NPA, a sub-unit within the Ministry of Home Affairs.) The MOC supervised the planning, construction, and maintenance of the nation's highway network. Its role was comparable to the Federal Highway Administration in the U.S. The actual operation of highways was not performed only by the MOC, however, but by a collection of public corporations. Different public corporations operated the expressway networks in different regions (e.g. the Tokyo region, the Osaka-Kobe region), while the MOC directly supervised the corporation operating rural expressways. The NPA (National Police Agency) exercised national responsibility for road traffic policy on all other roads. Its local counterparts were local police prefectures. In the 1970s and through to the 1990s, the NPA implemented computerized traffic control systems in all the prefectures of Japan. Together the MOC and the NPA shared jurisdiction for the nation’s road traffic and operations. Where the MOC was oriented toward expressways, the NPA's activities were focused on street networks.

Another, but less significant, player in the road transport sector was the Ministry of Transportation (MOT). With responsibility for vehicle safety regulations rather than infrastructure, the MOT played little role in ITS development.
The third sector was the communications sector. This included both private firms and government organizations. Six corporations commanded the business of supplying the NPA with traffic signals and traffic control systems in its local prefectures. Sumitomo Electric occupied a dominant position among these firms. On the public side, the Ministry of Posts and Telecommunications (MPT) was an important player in this sector. The MPT was responsible for regulating use of electromagnetic spectrum and so could decide whether new communication applications would be allowed to operate. In addition, in the mid-1980s the MPT began installing a mobile telecommunications infrastructure called "Teleterminal," which provided functionality for communicating with vehicles.

Finally, the Japanese technology sector consisted of MITI (Ministry of International Trade and Industry). Among its many activities MITI was charged with promoting new industry through the development of commercial technology. It promoted cooperative research activities, particularly in the automobile sector. Table 5-1 lists the sectors and the organizations within them.
Table 5-1: Sectors and Actors in Japan

<table>
<thead>
<tr>
<th>Sector</th>
<th>Organization(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>Toyota &amp; other automakers</td>
<td>Private firms</td>
</tr>
<tr>
<td>Roads</td>
<td>Min. of Construction (MOC)</td>
<td>Expressway planning, supervision of construction, roads administration</td>
</tr>
<tr>
<td></td>
<td>National Police Agency (NPA)</td>
<td>Local roads, traffic management</td>
</tr>
<tr>
<td></td>
<td>Min. of Transport (MOT)</td>
<td>Vehicle regulation</td>
</tr>
<tr>
<td>Communication</td>
<td>Sumitomo, other elec. cos.</td>
<td>Private firms</td>
</tr>
<tr>
<td></td>
<td>Min. of Posts &amp; Telecommunications</td>
<td>Spectrum allocation, Teleterminal</td>
</tr>
<tr>
<td>Technology</td>
<td>Min. of International Trade and Industry (MITI)</td>
<td>Commercial technology development</td>
</tr>
</tbody>
</table>

These organizations possessed the resources that would be needed to realize the ITS technical vision. Sectoral institutions organized those resources: the division of labor distributed expertise among them; the governance structures distributed authority; and the frameworks for funding defined sources of funding. These are examined in turn.

The first sectoral institution, the division of labor, distributed expertise needed to realize the ITS technical vision among many different actors. In the early 1970s Japanese automakers had developed expertise in in-vehicle electronics, and this gave them a base for developing navigation-related electronics. In addition, a few large electronics corporations had developed
considerable expertise in and responsibility for traffic electronics by serving as suppliers to the NPA's program in traffic control. Sumitomo Electric Corporation emerged as a particularly active corporation in traffic control, in-vehicle electronics, and other communications technologies. Industry possessed expertise needed for both the vehicle and the communication components of ITS.

Organizations in the road transport sector also had some research capabilities. Both the NPA and the MOC had internal research organizations. However, both ministries were primarily oriented toward planning, construction, and operations, and their research skills were less than those of industry. Furthermore, their expertise in electronics was much less than their expertise in civil engineering technologies, although it was somewhat supplemented by academic researchers, such as those at Tokyo University.

Thus expertise in all aspects of ITS existed but was distributed broadly. In order to assemble all the expertise needed a large number of actors would have to cooperate.

The second sectoral institution, governance structures, organized authority. ITS development in the second stage of development, that of technical field test, would require support from local authorities at the test site. Later stages of operational test and deployment would require the support of the national agencies with authority over all Japanese expressways and roads.

This authority was fragmented. As noted above, the NPA and the MOC each exercised
authority for operation of part of the nation's road infrastructure. The NPA was responsible for urban roads, and the MOC was responsible for inter-urban expressways. In order to implement ITS nation-wide, both organizations would have to support development and cooperate with each other.

Such cooperation, however, was not easy among Japanese ministries, who had a tradition of jealously guarding their "turf." Each ministry exercised authority within well-defined zones of responsibility and was careful to keep other ministries out of its affairs. Moreover, the road transport sector had a particularly bad record in inter-ministerial cooperation because of its fragmentation of authority. The need for cooperation arising from ITS development meant that the MOC and the NPA would have to cooperate without either side losing any jurisdictional authority. This would pose challenges to meeting the requirements of ITS.

Both the MOC and the NPA did, however, have a strong hierarchical authority. This gave them the ability to deploy technology. From the 1970s to the 1990s the NPA had implemented its computerized traffic control systems in each local prefecture in the country. Both by virtue of its administrative authority at the local level and its financial support for local investments, the NPA had ensured not only nation-wide deployment of traffic management but also standardized technology and organization design. As for the MOC, the operating organizations under it were the public operating companies of different expressway systems. Although formally independent of the MOC, the MOC exercised considerable influence over their decisions to deploy new technologies.
Players in other sectors also exercised authority needed for ITS development. The MPT (Ministry of Posts and Telecommunications) possessed authority for allocating electromagnetic spectrum for communications. In order to realize the ITS vision, the MPT would have to support the development program. On the industry side, automakers exercised authority over vehicle electronics. Their support would be needed to implement in-vehicle units.

Thus, the authority needed to test and implement ITS was distributed among three national agencies and various automakers. Overcoming jurisdictional rivalries between the MOC and the NPA would be the main obstacle to assembling all the needed authority.

The third resource required for ITS development was funding. The organization of funding in the relevant sectors was defined by various frameworks for funding. The most significant framework of funding was MITI (Ministry of International Trade and Industry). MITI served as a framework to promote cooperation and to fund development of commercial technologies. MITI's mission was to fund commercial technology development with a distant pay-off. It provided a framework for funding within which other groups could generate ideas and conduct research. Many of the actors doing substantive development work in MITI projects came from outside organizations.79

MITI’s resources were a good match for the needs of ITS development. ITS would require substantial funding in its second stage of development, that of technical field test. These needs would appear long before the technology could convincingly demonstrate benefits. With its

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technology orientation and its abundant resources, MITI could support ITS technology at this early stage.

Later stages of development would have to seek funds from ministries and industries active in the relevant sectors. ITS advocates seeking funding for operational field test (stage three) would probably have to look to the budgets of the NPA and the MOC. Either ministry’s budget would serve to support at least some development. Unlike the need for authority, the need for funding benefited from the multiplicity of ministries in road transport, for any one ministry could support development.

To obtain such funding from any ministry, ITS advocates would have to win support from the actors making budgetary decisions. In Japan those actors were usually the top-level bureaucrats in the ministries themselves. Although subject to parliamentary oversight, Japanese political institutions are those of a “strong state” in which the bureaucracy exercises considerable policy-making power. Available funding frameworks relevant to ITS -- the budgets of MITI, the NPA, and the MOC -- would not require broad supporting coalitions of elected officials to win approval. That would facilitate development, because funding requirements would not introduce a need for many additional actors. However, the political power of the bureaucracies contributed to inter-ministerial rivalries.

In summary, Japanese sectoral institutions organized the resources available for ITS development. In so doing they defined the coalitions that would be needed to realize the ITS

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technical vision. First, the division of labor distributed expertise among a large number of firms and ministries. To realize the ITS technical vision, a large number of expert organizations would have to cooperate. Second, the governance structures in the road transport sector divided authority among two agencies, the NPA and the MOC, and these had a history of difficulty in cooperation. To realize the ITS technical vision, developers would somehow have to overcome the barrier separating these two ministries. Finally, the funding requirements of ITS in its early stages could likely be met by MITI. Japan’s technology sector benefited from a framework for funding well-suited to the need of ITS. Later stages of development would have to be funded by some combination of NPA, MOC, and industry. The multiplicity of funding sources might increase the chances of receiving support, but it could also exacerbate the fragmentation of authority.

Although the other ITS development programs will be considered in later chapters, some anticipatory comparison with them can be made already here. Compared to other programs, three aspects of the Japanese program stood out. First, MITI as a framework for funding was better matched to the needs of ITS development than frameworks in most other programs. Second, jurisdictional fragmentation in the road transport sector was more pronounced in Japan than in some other programs. Finally, the comparatively weak influence of the Japanese legislature on funding decisions protected the development program from the distributional forces that strongly affected other programs. These relative strengths and weaknesses of Japanese institutions will become more apparent in comparison with other programs.

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Stages 1 & 2: MITI's CACS Program

We turn now from the analysis of Japanese sectoral institutions to the history of the development process. This next section corresponds to the third part of the sectoral institutions model of large technical system development (see Figure 3-3 in Chapter Three.)

The reader will recall that first part of the model was the technical vision; that was presented in the Chapter Four. The second part was the sectoral institutions; the immediately preceding section addressed that topic. The third part here, the development process, traces out how actors supporting the technical vision sought to assemble the needed resources in an environment structured by sectoral institutions. Development proceeded as a process of coalition-building. Finally, the chapter ends with the fourth part of the model, an analysis of the outcomes of development.

The story of ITS development in Japan begins with the formation of a group of ITS advocates in the Japanese research community. Researchers in industry and at Tokyo University adopted the ITS technical vision developed in the U.S. and championed its development in Japan.

As explained earlier, the FHWA’s ERGS experiment ran through the end of the 1960s and into the 1970s. Near the end of ERGS Japanese university researchers in traffic control joined researchers from Toyota and other firms in a visit to the experiment site. There the FHWA gave them a full tour and explained the design of a full system. With considerable experience of their own in vehicle electronics and electronic traffic control, the Japanese were keenly

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interested in this next step in the application of electronics to road transport.

Following their return these researchers defined an ITS technical vision of their own. This essentially duplicated the ERGS vision of vehicle-roadside communications for individual route guidance and area-wide traffic control. Figure 4-3 in Chapter Four illustrates this technical vision. Called CACS, the Japanese version of ITS provided a communication link between the vehicle and the roadside in order to realize individual route guidance and area-wide traffic control. The system used a loop antenna buried in the road for communication between the vehicle and a roadside computer. The entire road network was connected to a central computer that computed traffic management strategies.

The researchers who visited ERGS became advocates for ITS development. They formulated a vision of a large technical system and began working to assemble the resources required for development. To do this they had to seek out the expertise, authority, and funding required by the technical vision and had to assemble a coalition of the actors controlling those resources.

This coalition-building did not occur all at once. Since ITS development proceeded through discrete stages, developers only needed to assemble the coalition for the first stage. As development passed through successive stages, successive coalitions would be assembled to gather the resources for each stage.

Japanese development began immediately with the second stage, that of technical field test.

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Since they had already seen a complete first stage research experiment in ERGS, they combined their research stage with the technical field test stage. The resources needed for such a test were substantial. The technical field test would require expertise in vehicles, roads, and communications. It would require authority by transportation officials to conduct a test in an urban area. And it would require large amounts of funding to develop components and to equip hundreds of vehicles, intersections, and central traffic control.

The researchers set out to build a coalition of the actors controlling these resources. Assembling expertise posed no serious challenge. The ITS advocates were themselves researchers and possessed the expertise needed for development. The greater challenge lay in acquiring the needed authority and funding.

Obtaining funding for their envisioned technical field test was facilitated by the existence of well-suited framework for funding. Japan’s technology sector, embodied in MITI, existed to support just such activities and had the budgets to fund a technical field tests. The ITS technical vision matched MITI's institutional mission; the need for a large-scale and expensive technical field test was appropriate justification for public support. Furthermore, MITI had already supported the initial trip to the ERGS site.

The actors with decision-making power over MITI’s funds were first and foremost the ministry’s policy-makers themselves. However, support was also required by representatives of key industrial partners of MITI like Toyota and Sumitomo. Following the ERGS visit,

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these firms advocated a technical field test. With the needed coalition assembled, MITI's financial support was obtained for a second-stage technical field test.

Obtaining the authority needed for an urban test site proved more difficult. While MITI's mission matched the ITS vision, the same could not be said for the National Police Agency (NPA) or for its local police departments responsible for traffic control. When approached by the ITS developers, the NPA was lukewarm. An ITS field test, even if successful, offered no immediate benefits to the agency. Even stronger opposition came from the Tokyo Metropolitan Police Department, the agency responsible for traffic management at what became the proposed Tokyo test site. Both organizations saw a technical field test as excessively technology-push and lacking in near-term benefits.

Having become an early supporter of ITS, MITI played the role of coalition-builder. To advance development MITI had to convince the recalcitrant members to join the coalition. To do this, MITI appealed to their financial interests. After lengthy negotiations with NPA officials, it was agreed that MITI would provide funds to the NPA to participate in the test. The National Research Institute of Police Science, the research organization within the NPA, became a participant in the test using funds supplied by MITI. With NPA on board, the local Tokyo Metropolitan Police Department also agreed to the field test. Thus, MITI used funding to assemble the needed coalition for the technical field test.

With the coalition built, development could proceed. In 1973 MITI launched the

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Comprehensive Automobile Traffic Control System (CACS). This was a six-year field test that tested the utility and technical feasibility of traffic control and route guidance using vehicle-roadside communications. Its budget amounted to $25 million (about $86 million in 1991 dollars.) This was considerably more than the FHWA had invested in ERGS. Indeed, throughout the 1970s and well into the 1980s no other ITS program anywhere approached CACS in size.

CACS picked up where ERGS had left off, moving ITS development from the research stage to the technical field test. The difference was substantial: where ERGS had been conducted at two intersections, CACS equipped a total of ninety-eight. A large number of vehicles were also outfitted for CACS: one thousand vehicles served as simple probes, carrying transmitters providing only their identification code, and another 330 vehicles carried the full bi-directional communication system to receive guidance to their destination. Knowledge of technical functionality was still the goal, but now on a real-life scale.

As comparison with other programs will show, CACS was most noteworthy for what didn't happen. The technical field test was executed according to plan, remaining tightly focused on the original ITS vision. Only one large field test in one installation was undertaken. Because it was protected from legislators’ concerns about the geographic distribution of public funds, it did not fracture into multiple small tests. Furthermore, with twelve industrial companies involved, participation was not unnecessarily expanded to accommodate additional interests. In all these respects the experiences of CACS was unusual among ITS programs around the

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At the end of its six-year lifetime, CACS was terminated as planned in 1978. Evaluations of the field test indicated that the system's technical functionality was adequate. Some preliminary estimates of benefits were also produced. Estimated reductions in travel times were in the range of nine to fifteen percent. Although such data was quite tentative, one thing was clear: ITS's promise had not been disproved by the field test.

In one area the ITS vision realized in CACS showed itself to be inadequate. The CACS technology design (like the ERGS technology design) integrated the vehicle and the roadside too much. With data processing intelligence divided between the on-board units and the roadside computers, the system was useless without extensive implementation of both.

This close technical integration of vehicles and roads contradicted the governance structures for roads and vehicles. Private firms exercised authority over vehicles, and public agencies exercised authority over roads. These organizations were independent and had no reliable coordinating mechanisms between them. The mutual dependency of the vehicle and the roadside in the technology design created a "chicken-and-egg" problem in implementation: public authorities would not install infrastructure unless private vehicles were already equipped, and consumers would not purchase systems unless public infrastructure was already installed.
This mismatch between the technology and the governance structure was resolved by changing the technology design. A change in the design eliminated the interdependency. Toyota and other automakers adopted a strategy of developing autonomous navigation systems. The on-board system would be redesigned to incorporate enough functionality to allow it to operate without infrastructure. These autonomous units could be deployed first, and the infrastructure could follow. Here the institutional structures of the road and vehicle sectors shaped the design of the technology. If automakers and public agencies were autonomous of each other in the social realm, then in-vehicle units and roadside computers would be autonomous in the technical realm.

This de-coupling of vehicle and roadside technology shaped long-term strategy. Throughout the 1980s ITS development would advance as two activities, one for on-board systems and the other for roadside infrastructure development. Industry would develop autonomous on-board components like navigation systems to guide drivers to their destination. The responsible public agencies would sponsor field tests to integrate vehicles into a roadside communications system. Eventually the two would be rejoined in a functioning vehicle-roadside communication system for route guidance and traffic control.

After CACS, development was ready to advance to the third stage, that of operational tests. Operational tests would examine transportation agencies' ability to implement and operate systems. The focus would shift away from technical functionality to system benefits.

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Operational tests would impose new resource requirements. With their focus on benefits for operating agencies, those operating agencies would have to lend their authority to development. The locus of ITS development would move from MITI to the National Police Agency (NPA) and the Ministry of Construction (MOC). In addition, an appropriate framework for funding would have to be identified, and the actors controlling that funding would have to support development. The third stage of ITS development would require many additional participants in the supporting coalition.

At the conclusion of CACS in 1979, MITI, Toyota, Sumitomo, and other advocates of ITS development could not assemble the coalition needed for an operational test. Neither the MOC nor the NPA were willing to host operational tests. Although automakers emerged from CACS ready to assume the lead with in-vehicle systems, public sector organizations were still not committed to ITS. Nor could MITI directly influence these two agencies' actions. Granted, the channeling of MITI funds through the NPA had won the latter's support for the Tokyo field test. But continued development would require major commitments by those agencies, something beyond MITI's control.

MITI faced the danger that ITS development might be terminated, much as it had been terminated in the U.S. True, development in Japan had fared better than in the U.S.: ERGS had only accomplished the first stage of development (research), while the Japanese program had made it through the second stage (technical field test). However, the inability to bring the MOC and the NPA into the supporting coalition meant that development might ultimately fail
here as well.

At this point MITI devised a strategy to avoid failure. If development could not advance, at least it would not fail either. MITI would keep ITS development alive while waiting for the operating organizations to support it.

To keep ITS alive MITI in 1979 created a new organization, the Association of Electronic Technology for Automobile Traffic and Driving (known by its Japanese initials, JSK.) JSK would serve as a repository for knowledge accumulated to date. JSK had a limited charge and budget, to be used to conduct surveys, hold conferences, and publish reports. It hosted continued research, held occasional conferences, and in 1985 even promoted a small field test at the Science Exposition in Tsukuba City. However, the association served primarily to prevent a loss of knowledge than to actively move it forward. Substantial forward movement would require the commitment of the NPA and the MOC. JSK ensured the continuity of knowledge as development paused to build a new coalition for a new stage of development.

Thus by 1980 ITS development had advanced through technical field test and was ready for operational test. In the process, it had changed. First, the technical design had changed: the close coupling between the in-vehicle unit and the roadside infrastructure had been relaxed to better match the independent authority of public road ministries and private automakers. Second, the program design had changed: some funding was re-channeled through the NPA to win authorization for a field test in metropolitan Tokyo. Finally, organization design had been
performed: the JSK Association would host ITS development until it could advance to the next stage. The new organization would keep ITS knowledge alive and buy MITI time to build the next coalition.

MITI ultimately succeeded. Seven years after the end of CACS one of the national transportation organizations launched an operational test of its own, and the other organization soon followed.
Stage 3 (Operational Test): RACS

The NPA and the MOC were primarily operating organizations, not research organizations. As such, they had little interest in investing resources in a technology advocated by researchers but offering little evidence of benefits for road transportation. Moreover, unlike MITI they did not have responsibility for commercial technology, so the potential benefits to automakers and consumer electronics firms were not part of their evaluation of ITS.

Nonetheless, MITI’s patient strategy eventually paid off. For reasons only tangentially related to the uncertain benefits of ITS, both ministries eventually supported operational tests.

The first opening for continued development appeared in the MOC. In the early 1980s an opportunity arose within the MOC in which ITS development could be supported. The ministry’s control over public rights of way alongside expressways brought it into contact with information infrastructure providers who wanted to lay cables. In exchange for leasing its rights of way, the MOC gained access to a powerful communications infrastructure running alongside its expressways. With this new resource available, the MOC was open to suggestions about how it might use it to improve expressway transport. The idea of some application of communications to expressway transport made sense, since the backbone for such a system was already in place. The MOC looked at how it might apply CACS technology. A transportation ministry with the authority needed to realize ITS was now ready to support development.
At first the MOC used CACS technology only for the simple application of reporting travel times on expressway links. Travel times were calculated using vehicles as probes, and these times were displayed on variable message signs for other drivers on the expressway. Then in 1984 the MOC established an association called the Highway Industry Development Organization (HIDO) to research new industrial fields related to highways.87 HIDO provided a home within the MOC for ITS research and interest. HIDO began planning an operational test of a vehicle-roadside communication system.

In 1986 the MOC launched an operational test. Named the Road Automobile Communication System (RACS), this operational test integrated ITS into a transportation agency (the MOC) in order to learn about its benefits. Planned to run for three years, RACS would end in 1990. RACS marked the beginning of the third stage of ITS development in Japan. The transition from a technical field test to an operational test had taken seven years, from 1979 to 1986, but it had finally occurred.

Like other systems, RACS consisted of an in-vehicle unit, a communications medium, and roadside information centers. There were two changes, however. First, RACS used the autonomous in-vehicle units developed by automakers after CACS. Second, instead of using the in-road loop antennas tested in CACS, RACS used microwave beacons to link vehicles and the roadside. The microwave beacons were capable of high-capacity burst communications with vehicles moving past at highway speeds. A passing vehicle could transmit or receive the data equivalent of a one-page facsimile. This capacity would allow for generic communication

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capabilities as well as route guidance and traffic control. Figure 5-1 shows the RACS system design.\textsuperscript{88} (Its different kinds of microwave beacons corresponded to three kinds of information: simple location data, traffic flow data, and generic "individual communications" such as facsimile.)

The MOC had little difficulty assembling the resources needed for the RACS operational test. A total of twenty-five automakers and electronics firms were ready to collaborate with the ministry in the test. Together they possessed the required expertise. These firms were also willing to contribute funding. The MOC contributed only $5 million for RACS, while each participating firms’ contribution amounted to perhaps half that amount.\textsuperscript{89} Finally, the MOC possessed almost all the needed authority to conduct a test on the expressways joining Tokyo with nearby Kawasaki City and Yokohama City.\textsuperscript{90} A spin-off from this project was the Japan Digital Road Map Association, which was a cooperative effort to define standards for digital road maps used in in-vehicle units.

The MOC lacked authority for one requirement of the operational test, however. As noted earlier, the Japanese Ministry of Posts and Telecommunications (MPT) exercised authority in the communications sector. The MOC’s use of microwave beacons for bi-direction communications between the vehicle and the roadside beacons required authorization from the MPT. This was obtained for the operational test, with the understanding that such authorization would be reviewed before deployment could take place.

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Figure 5-1:
The Road Automobile Communication System (RACS)
With the full supporting coalition assembled and all needed resources obtained, RACS ran from 1986 to 1990. Vehicles on freeways uploaded their destinations and travel times and received traffic data and route guidance information.
Stage 3 (Operational Test): AMTICS

Following its participation in the early CACS test, the NPA (National Police Agency) had shown little interest in ITS technology. However, if the optimistic benefits forecasts from CACS failed to impress the NPA, the sight of the MOC conducting an operational test did. Shortly after RACS began, the NPA launched its own operational test.

The MOC's operational test threatened the NPA. The two agencies were long-time rivals in the domain of road transport, and the emerging field of vehicle-roadside communications was relevant to both agencies' jurisdictions. Not wanting the MOC to assume this responsibility alone, the NPA closely watched the RACS operational test to see that the MOC did not infringe on its jurisdictional prerogatives.

Shortly after the launch of RACS, the NPA responded with its own field test. A number of factors came together to promote the activity. First, as noted, the MOC's RACS test put competitive pressure on NPA. Second, the NPA's program to implement traffic control systems in all prefectures was approaching completion. Large budgets would soon be freed and a driver information system might justify continued spending.

Third, a new communications medium had become available that could be used for the system. Japan's Ministry of Posts and Telecommunications (MPT) was developing a communications infrastructure called Teleterminal to allow for mobile data communications. Teleterminal was similar to cellular telephone in that a single station provided communication channels in a
surrounding area within a radius of three kilometers. The MPT planned to install three Teleterminals in Tokyo in 1989, and the NPA's field test would serve as an early experimental application for the system. This would keep the costs of an operational test low.

With these factors creating an opportunity for a new initiative, the NPA launched the Advanced Mobile Traffic and Information System (AMTICS) in 1987. AMTICS closely followed the ITS vision, providing real-time traffic data to vehicles equipped with autonomous on-board systems. Figure 5-2 shows the AMTICS system.

Although RACS and AMTICS both closely followed the original ITS technical vision, the two systems were technically incompatible with each other. AMTICS used a different communications medium than RACS. The wide-area Teleterminal system used in AMTICS was incompatible with RACS's microwave beacon approach. Teleterminal did not have as much capacity as microwave, nor could it perform bi-directional communication to a single vehicle. Thus it could not support the individual communication services foreseen in RACS. AMTICS provided only dynamic traffic information to serve the on-board system.
Figure 5.2: The Advanced Mobile Traffic and Information System (AMTICS)
In AMTICS the NPA worked with an association of some sixty automobile and electronics firms to plan, implement, and test ITS.\textsuperscript{93} Most funding came from the industry participants. In the six-month field test the NPA paid $1.9 million and the industry partners paid their own expenses (a sum estimated to be many times than the NPA's investment.)\textsuperscript{94} The NPA had no difficulties obtaining authorization for spectrum use from the MPT, because AMTICS ran on the MPT's own Teleterminal communication system.

AMTICS underwent two field tests in three years. In 1988 a small three-month pilot test was held in Tokyo. In 1990 a six-month field test was held near Osaka. Overall the program lasted three years.

Thus by 1990 ITS development in Japan had completed the third stage of development, that of operational tests. ITS development, however, was far from complete. The governance structure of the transport sector had split the technology into two parallel development programs using incompatible technology. Only by joining together, however, could ITS developers create a single system. Considerable work remained to overcome the institutional divide separating the NPA and the MOC.

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Developing a Unified System: The Vehicle Information and Communication System (VICS)

Two interrelated challenges remained for ITS development in Japan. First, the incompatible RACS and AMTICS systems had to be integrated. Second, development had to advance to the fourth stage of development, that of deployment. Both these challenges were addressed in the creation of the Vehicle Information and Communication System (VICS). VICS was to consist of a single technical design and an operating organization to deploy infrastructure.

Significantly, the 1991 proposal to move beyond RACS and AMTICS to VICS was made by industry. This reflected the enduring commitment by Japanese automakers and electronics firms to ITS, as well as the lack of consensus among the participating public agencies about how to proceed. The attitudes of industry and public agencies toward ITS merit additional description.

Throughout the years of ITS development, Japanese industry had exhibited a strong commitment to ITS. The original proposers of CACS in 1973 included researchers from Toyota Motor Corporation, and both Toyota and Sumitomo Electric Corporation were deeply involved in that project. MITI’s early championing of ITS was justified by that ministry’s mission to promote commercial technology rather than transport technology. Later, in RACS and AMTICS, most funding came from the industry participants. ITS in Japan was born in the context of commercial technology.

Following CACS Japanese corporations took the lead in developing in-vehicle units.

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Responsibility for solving the "chicken-and-egg" problem of the vehicle-roadside system was shouldered by industry, which deployed autonomous in-vehicle units in advance of roadside infrastructure. These units were developed and marketed throughout the 1980s, and by 1993 some 500,000 units had been sold -- a number even more remarkable when compared with the near total absence of similar consumer sales in the U.S. or Europe. Firms developing or marketing such units included automakers (e.g. Toyota, Honda, Nissan), electric companies (e.g. Sumitomo Electric), and consumer electronics companies (e.g. Panasonic, Sony, and Hitachi).

Besides making the private sector the leader in development, these corporations played a vital role in advancing development in the public sector. When the locus of development shifted from MITI to NPA and MOC, the agencies' industry partners provided continuity. Although MITI, the MOC, and the NPA did not have many direct dealings between themselves, they worked with overlapping sets of corporations in industry associations. Many of the same firms belonged to MITI's JSK association (Association of Electronic Technology for Automobile Traffic and Driving), MOC's HIDO association (Highway Industry Development), and NPA's JTMTA association (Japan Traffic Management Technology Association). The corporations helped to transfer technology and pushed public agencies to act.

Corporations also bore most of the costs of development. After MITI's initial sponsorship of CACS, public investment in ITS was far lower than elsewhere in the world. Although funding figures for RACS and AMTICS were never formally published in Japan, they were informally

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estimated at $5.4 million and $1.9 million respectively. In contrast, the estimated investment made by each company participating in these projects was estimated at $4.5 million.96 Indeed, AMTICS was characterized as a project almost entirely funded by the membership fees of the participating corporations.97 Thus industry can be credited with being the driving force behind ITS development in Japan.

Public agencies offered a striking contrast. As noted, with the exception of MITI they invested relatively little in research and development. More significantly, their actions were powerfully shaped by the dynamics of bureaucratic rivalry. Although this promoted ITS development insofar as it motivated NPA to launch a program to compete with MOC, rivalry also led to some problems in development.

Besides splitting development into two programs, bureaucratic rivalry also led to changes in the communication media used by both NPA and MOC. Both ministries in the transport sector experienced difficulties with the MPT (Ministry of Posts and Telecommunications). Following RACS, the MPT refused to authorize the microwave uplink. This decision nullified much of RACS' functionality for non-traffic services like facsimile transmission. The MPT allegedly was concerned that such functionality would compete with its own development of personal communication services. Then, following AMTICS, the NPA sought to free itself from any dependence on the MPT. To do this, the NPA switched to infrared communications to link the vehicle and the roadside. Unlike microwave spectrum, the visible spectrum (including infrared) was not regulated by the MPT, so the NPA could develop ITS.

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independently of the MPT. The NPA used technology design to free itself from the MPT. In sum, bureaucratic rivalries shaped the actions of public agencies throughout the ITS development programs.

The upshot of this was that public agencies advanced more slowly than industry in developing ITS. Although in-vehicle units had been developed and deployed by 1990, roadside infrastructure development remained divided into incompatible systems. The inability and unwillingness of public agencies to join in a single effort hampered deployment.

In the fall of 1991 an industry-led group initiated a reconciliation between RACS and AMTICS. They proposed a unified system called Vehicle Information and Communication System (VICS). The group of "VICS promoters" consisted of two automakers (Toyota and Nissan), five electric companies (Sumitomo Electric, Oki Electric, Hitachi, NEC, Matsushita Communication), and the industry associations affiliated with the NPA, MOC, and MPT. They were led by Shoichiro Toyoda, president of Toyota Motor Company. They proposed a planning organization to design an integrated technical system (to be called VICS) and to create an organization to operate the system.

The planning organization, called the VICS Promotion Council, was a broad-based membership organization that united the various corporations active in development. At the time of its first meeting, in October 1991, its membership numbered two hundred. Although the NPA, MPT, and MOC were not themselves members, their respective industry

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associations provided a link. The Council was organized into various committees for research planning, business planning, and field test. Thus by the end of 1991 ITS development in Japan had begun the next step in development. Activities to merge the two parallel programs were underway, and the step to the deployment stage was begun.

It is worth noting where other programs around the world stood at this point. In 1991 the U.S., the federal government was about to enact legislation that would resume ITS development by USDOT. After two decades of inactivity, the U.S. program would soon dwarf those of Japan and Europe in the size of its public investment. In Europe Siemens was at a similar stage of development as the Japanese. It had completed a large-scale technical field test and was focusing on the design of an operating organization for its system. Two other European programs, DRIVE and PROMETHEUS, were both engaged in early-stage research. The members of VICS in Japan and Siemens in Germany were the two programs most advanced in development at this time.
Technology and Organizational Design

The VICS Promotion Council had to perform two tasks. First, it had to design the VICS technology, which would merge the RACS and AMTICS systems. Second, it would have to design an organization to operate the system once deployed.

In both technology design and organization design, one principle was clearly in evidence: organizational jurisdictions were to be honored. The overall system was divided into a variety of pieces each of controlled by the actor with authority in that jurisdiction. These various pieces would then be linked and coordinated through a central organization, the VICS Center.

Two functions for the VICS system fell under public jurisdiction, traffic information collection and information diffusion. Here the MOC and the NPA each would use their own preferred technologies. For information collection each of them already had their own technologies in place for their existing traffic management systems. For information diffusion -- the vehicle-roadside link at the heart of the ITS technical vision -- each used their own proprietary technology. On the MOC’s expressways, microwave beacons (“radio beacons”) would transmit information to passing vehicles. On the NPA’s surface streets, infrared beacons and wide-area FM broadcasts would be used.

This technology provided testimony to the difficulty of inter-agency cooperation. RACS and AMTICS were not so much merged into a system as they were overlaid into a system. Since the RACS and AMTICS performed information collection independently, VICS would use
both sources. Similarly, since RACS and AMTICS used different media for information provision, VICS would use all those media. The VICS technology design merely incorporated the multiplicity of the media, performing the minimum integration of RACS and AMTICS.

The automakers suffered the most from this aggregation of different technologies. With VICS designed as the union rather than a synthesis of RACS and AMTICS, industry participants had to include compatibility for each agency's media in their consumer units. In-vehicle units had to include microwave, FM, and infrared receivers. Figure 5-3 shows the overall design of VICS. 99

This design emerged in the course of preparation of another operational test. The VICS test took place in the fall of 1993, some two years after the launch of VICS. The scale of the test was relatively small, some 230 million Yen (about $2.3 million), and was paid for by the industry members of VICS. It culminated in a very brief two-day public demonstration at which 1600 attendees could ride and inspect forty-five equipped vehicles. 100

The VICS organization design also followed jurisdictional boundaries. Responsibility for information gathering and diffusion lay with the MOC and the NPA. Significantly, the two public organizations would bear the costs of installing additional roadside infrastructure and for gathering data. In-vehicle systems would be marketed by private firms. Ultimately, the costs here would be paid by consumers. By 1995, this part of VICS was already widely implemented, with an estimated one million in-vehicle units were already sold. 101

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Figure 5-3: The Vehicle Information and Communication System (VICS)
At the heart of VICS, however, the different players had to come together. The data processing and editing center, called the VICS Center, would interact with all the other parts. Launched in July 1, 1995, the VICS Center was the operating organization for the system.\textsuperscript{102} It would be a single data processing point to collect data from various sources and to prepare it for transmission by the various media.

The organization design of the VICS Center allocated authority and financial responsibility. Authority over the VICS Center would be exercised by public organizations.\textsuperscript{103} The MOC and the NPA had stood firm; they would not yield authority to private groups.

Financial responsibility for funding the VICS Center, however, would be born by the industry partners. For every in-vehicle unit sold, a “technology fee” would be paid to the VICS Center. For inexpensive units with only text displays, firms would pay 500 Yen fee per unit (approximately $5); for sophisticated displays with graphical map displays, firms would pay 2000 Yen fee (approximately $20).\textsuperscript{104} To get the VICS Center started, an initial sum of 2 billion Yen ($20 million) was paid by participants in the VICS program.

Overall, the cost of nation-wide deployment was estimated at 1.2 trillion Yen ($12 billion) over twenty years. Of that sum, two-thirds (800 billion Yen, or $8 billion) would be born by consumers purchasing in-vehicle systems, and almost one third (370 billion Yen, or $3.7 billion) would be paid by public organizations deploying the various roadside beacons. The cost of information collection was counted as zero, since existing traffic management systems

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already possessed traffic data. That left only 2.5% of the total cost (33 billion Yen, or $330 million) to be born by the VICS Center. This sum would paid out of the technology fees and initial funds mentioned above, and would presumably be paid by consumers. However, consumers would not be assessed any service fee for the provision of the VICS data. All variable costs for information provision were covered by a fixed fee included in the purchase price of an in-vehicle unit.

The public benefits of VICS over twenty years were estimated at 7.7 trillion Yen ($77 billion) over twenty years. Almost all of that (7.3 of the 7.7 trillion Yen) would come from reduced hours of driving time of the Japanese public. This impressive-sounding figure was actually surprisingly low. Drivers who invested the hundreds or thousands of dollars for a VICS in-vehicle unit could expect to save an extra 2 minutes per day of driving time.

The 2-minute figure could be obtained through a few simple logical steps. The benefits of VICS equal

\[
= 7.3 \text{ trillion Yen per 20 years for all Japan (claimed the VICS Center)}\\
= 7.3 \text{ billion per 20 years (because 100 Yen = $1)}\\
= 7.3 \text{ billion per 7300 days (because 20 years = 7300 days)}\\
= 10 \text{ million per day (divide by 7300)}\\
= .55 \text{ per day for each vehicle (divide by the estimated 18 million equipped vehicles).}
\]

If the 18 million vehicles are all single occupancy, and if drivers value their time at $16.50 per hour, then the $.55 that VICS saves represents 1/30 of an hour. 

*VICS was estimated to save*
drivers 2 minutes a day.\textsuperscript{105}

This low figure suggests that a rational cost-benefit analysis could not explain the reason for VICS development in Japan. A more likely reason for VICS development was the anticipation that the system would stimulate new and unforeseen applications and uses that would bring new benefits. Ultimately, however, it supports the thesis of this study that large technical system development cannot be adequately explained by a rational actor model of development.

The VICS Promotion Council estimated that VICS could begin regular operations in spring of 1996. In the first seven years deployment would begin in the Tokyo, Osaka, and six other areas of Japan. Within eighteen years deployment over the entire country would be achieved.

Thus by 1995 the Japanese had advanced to the point of creating a plan for nation-wide deployment. Yet the difficulties experienced in merging RACS and AMTICS suggested that the future would not be as smooth as predicted. Certainly, the creation of a plan that unified the technology and allowed for development indicated that the divisions between MOC and NPA were being overcome. However, they were only barely overcome. The VICS system design was simply an overlay of two separate systems, and the deployment plan predicted small benefits. Whether the divisions among the partners could be permanently overcome remained a question.
Other Activities

In the early 1990s other Japanese development programs also began applying electronics, computers, and communications to road transport. These went forward in a number of independent programs in different ministries. Characteristically, each program was associated with a single ministry.

Around 1990 three ministries launched programs related to vehicle automation. The MOC (Ministry of Construction) launched a program called Advanced Road Traffic Systems (ARTS) in 1989; MITI launched a program called Super Smart Vehicle System (SSVS) in 1990; and in 1991 the Ministry of Transport, a latecomer to the field, launched a program called Advanced Safety Vehicle (ASV) program. In the field of traffic information, the National Policy Agency launched the Universal Traffic Management Systems (UTMS) program in 1993.

As later chapters will recount, this explosion of activity in the 1990s occurred in overseas programs as well. In Europe, the U.S., and Japan, ITS programs were underway.

In January 1994 the many programs in the various ministries together formed a single joint organization called the Vehicle Road Traffic Intelligent Society (VERTIS). VERTIS was designed to unite the many different organizations and programs performing ITS development in Japan. It consisted in two main bodies, one for the public sector and the other for the private sector. The VERTIS Inter-Ministerial Council was a committee of the five public
sector actors. The VERTIS Promotion Council was the industry and academic association with hundreds of members.

VERTIS would serve as the national forum for issues in ITS development, broadly defined. Its first task was to represent Japan at an international ITS World Congress in November 1994. Its ultimate goal was to create a single ITS technology design and development strategy for all of Japan. Whether VERTIS would actually succeed in coordinating the activities of the independent ministries, agencies, and firms in it was a question for the future. Figure 5-4 shows VERTIS.
Figure 5-4: The Vehicle Road Traffic Intelligent Society (VERTIS)

Organizational Structure for Vehicle, Road and Traffic Intelligence in Japan (VERTIS)
Outcomes of Development

This account of Japanese activities ends in 1995, before the ITS development process was complete. Still, by that time the original technical vision from ERGS was being deployed as VICS, and the final form of the system could be clearly discerned. Furthermore, the national VERTIS organization had been created to coordinate all development programs in the country. Therefore, this account captures the salient events to date.

So far we have examined three of the four parts of the model of sectoral institutions. The first two parts were the technical vision and the sectoral institutions. The third part was the development process, the dynamic activity in which ITS advocates assemble the resources needed for the technical vision. Here we consider the fourth part, the outcomes of development. These are the technology design, the program design, and the organization design.

The technology design of ITS in Japan manifested three influences of sectoral institutions. First, the final VICS design was remarkably similar to the original ERGS-inspired design of twenty years earlier. This manifested the frameworks for funding in Japan. The existence of a framework for funding like MITI allowed development to advance through the technical field test stage (where ERGS in the U.S. had stopped for lack of funding.) In addition, the autonomy of all bureaucracies in their funding decisions protected development from distortions induced by the need to assemble large coalitions.

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Second, the VICS technology design consisted of an overlay of two systems with incompatible communication media. This lack of integration reflected the governance structure in the road transport sector which also lacked integration. The fragmentation of authority between the MOC and the NPA led to multiple incompatible communication media.

Third, the lack of a nation-wide system architecture or coherent vision of ITS manifested the autonomy of all ministries. Only in 1995 did the many actors involved in ITS come together in VERTIS to coordinate their design activities. Each ministry autonomously designed its own technology.

The program design manifested many of the same influences. Rather than a national program, ITS development in Japan unfolded as so many parallel programs in independent ministries. The governance structure in the road transport sector led to the bifurcation of development into the parallel RACS and AMTICS programs. In the 1990s a variety of independent programs were launched in different ministries.

The design of new organizations proved to be one of the most difficult development tasks in Japan. The ITS technical vision required cooperation between different actors, and to realize this cooperation new organizations were created. However, concerns about jurisdiction, especially among ministries and agencies, made them reluctant to enter into cooperative arrangements. The design of the VICS Center organization sought to allow cooperation while respecting the autonomy and jurisdiction of each party. Given the hesitancy of the MOC and

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the NPA to collaborate, the success of VICS after 1995 was far from certain.

Examined in isolation, ITS development in Japan appears in many respects unremarkable. The reader might be unimpressed to learn that VICS in 1995 closely resembled the ERGS technical vision of 1970. However, when compared to ITS programs in other contexts, the Japanese experience is remarkable. Few other programs managed to pursue the ITS technical vision with so little distortion. It is to those other programs that we now turn.
Chapter 6

ITS DEVELOPMENT IN EUROPE

In the 1980s three ITS programs got underway in Europe. These were the ALI-SCOUT development program by Siemens, the PROMETHEUS Program by the European automobile industry in the EUREKA framework, and the DRIVE Program in the European Commission. Each planned to link vehicles and roadside into a system.

The three European activities proceeded as parallel, loosely-connected initiatives in three different contexts. Siemens' ALI-SCOUT program was an industry initiative launched at the national level in Germany; it preceded the other programs by nearly a decade. PROMETHEUS and DRIVE were both pan-European initiatives and were close to each other in time, but they differed in their composition. PROMETHEUS was an inter-industry program, while DRIVE was a government-industry program.
ALI-SCOUT: Sectoral Institutions

Siemens' ALI-SCOUT development program unfolded in the institutional context of a single country, Germany. In this it differed from the two later programs, both of which were European in scope and both of which unfolded in pan-European institutions. Although the program's technical vision was the same as that in ERGS, the institutionally-conditioned availability of resources in Germany was quite different than in the U.S. or Japan.

An examination of the relevant sectoral institutions in Germany reveals the structures that shaped ALI-SCOUT development. The relevant sectors were the automobile and communications industry sectors and the road transport and technology policy sectors.

Germany's automotive sector was (and is) the largest industrial sector in the country. Firms like Daimler-Benz, Volkswagen, BMW, Porsche, and others were world-class manufacturers. In this sector resided abundant expertise, funding, and de facto authority for the contents of many of Europe's vehicles.

Germany's road transport sector was governed by public sector institutions organized in a federal system. At the national level a single Federal Ministry of Traffic (MOT)\textsuperscript{108} oversaw the transport network, including the national highway network. Transport agencies at the state level (Laender) enjoyed substantial autonomy, as did departments of transport at the city level.

In the transport-related communications and electronics sector, the firms Bosch and Siemens

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exercised leadership. Bosch was one of the world's largest suppliers of automotive components, particularly automotive electronics. The country's largest electronics firms was Siemens, which served a broad array of markets in everything from household appliances to hydroelectric turbine generators. Siemens produced electronics for many different aspects of road transport.

Finally, like Japan but unlike the U.S., Germany possessed an explicit technology policy sector. The Federal Ministry of Research and Technology (MRT) provided public support for private firms developing commercial technology, often in the form of grants. Like MITI it could help private firms in the early stages of technology development.

Within these four sectors, the resources needed for ITS development were organized according to sectoral institutions. Expertise, authority, and funding were organized according to a unique division of labor, governance structure, and frameworks for funding.

The division of labor in Germany and the associated distribution of expertise were unlike that of any other country. One single firm -- Siemens -- possessed nearly all the expertise to develop ITS single-handedly. On the roadside Siemens was one of the world's leading suppliers of traffic management systems. In the 1960s the firm developed Europe's first computer controlled traffic signal system in Berlin. By the mid-1990s Siemens had designed and installed traffic control systems for over two hundred cities in more than fifty countries. Within Germany, where most cities had traffic control systems in place, Siemens had installed
Siemens also possessed expertise in communications and vehicle electronics. It was a leading automotive electronics supply firm and was increasing its commitment to the sector. During the 1980s it purchased the automotive electronics business of Bendix in the U.S., one of the leading North American suppliers in that market. As a vendor of telecommunication switching devices and telephone equipment, it also possessed expertise in telecommunications.

Thus, all by itself Siemens possessed the full range of expertise to develop ITS. It produced roadside infrastructure for traffic management; it produced in-vehicle electronics; and it produced communication systems. Even though expertise was only one of the three needed resources, it provided the firm with a very solid base from which to develop ITS.

Other actors in other sectors also possessed expertise. City transportation departments operated traffic control systems. Automakers installed vehicle electronics for engine control, and some firms like Daimler-Benz, had diversified into electronics. Bosch, in particular, possessed considerable expertise in in-vehicle devices such as radios, anti-lock brakes, and ignition systems. Nonetheless, no other actor in Germany possessed the full range of expertise that Siemens did.

The second resource relevant to ITS development was authority. Here most resources lay with public agencies. The governance structure in the transport sector reflected Germany’s federal
system, in which state and city government exercised authority for transport policy within their jurisdictions. Although the federal government controlled considerable sums for procurement, lower levels of government possessed a high degree of autonomy.

Siemens also possessed some resources here. Although it possessed no formal authority for roadside infrastructure, the firm did have established relationships with many local governments operating traffic control systems. These relationships gave the firm easier access to decision-makers.

Finally, three frameworks for funding organized the financial resources needed for ITS development. The MRT (Federal Ministry of Research and Technology) constituted a framework of funding for early technology development. Private firms could request support from the MRT for commercial development projects. In the road transport sector the MOT (Ministry of Transport) possessed budgets for infrastructure deployment that could fund ITS development at later stages. Local transport agencies also possessed transportation funding resources. Finally, private firms possessed funding resources in their own internal budgets. Of all three frameworks for funding, the MOT budgets seemed the best fit to the later needs of ITS operational tests and deployment. Table 6-1 shows the relevant actors in the sectors.
Table 6-1: Sectors and Actors in Germany

<table>
<thead>
<tr>
<th>Sector</th>
<th>Organization(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>Daimler-Benz &amp; other automakers</td>
<td>Private firms</td>
</tr>
<tr>
<td>Roads</td>
<td>Ministry of Traffic (MOT)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State and Local Agencies</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>Siemens</td>
<td>Traffic, communication, auto electronics</td>
</tr>
<tr>
<td></td>
<td>Bosch</td>
<td>Vehicle electronics</td>
</tr>
<tr>
<td>Technology</td>
<td>Ministry of Research and Technology (MRT)</td>
<td>Funding for commercial technology development</td>
</tr>
</tbody>
</table>

The ITS Technical Vision

The ITS technical vision was introduced in Germany at approximately the same time as in Japan.

In 1970 a researcher at the Technical University of Aachen proposed a vehicle-roadside communication system for route guidance and traffic control. Eventually researchers at Bosch supported the technical vision and together they planned a technical field test. This version of ITS was called ALI (Route Guidance and Information System for Drivers). 113

The technical vision in ALI was the same as in ERGS and in CACS. Figure 4-4 in Chapter 4 showed all three systems, with their characteristic components. However, where ERGS had been a stage-one research experiment, ALI (like CACS) would be a stage-two technical field test.
Bosch pursued the same vision as the ITS advocates in Japan, advancing directly to the technical field test stage. ALI would test 400 vehicles at 83 intersections on a 150 km (100 mile) network of highways.

By the late 1970s Bosch had succeeded in assembling all the needed resources for a field test. It built a coalition with other firms to assemble the full range of expertise. In winning Volkswagen and the Heusch/Boesefedt traffic engineering firm as partners, Bosch assembled the needed expertise in the vehicle, the roadside, and the communications link. To acquire the needed authority for a test on public infrastructure, Bosch sought and won the support of the MOT. Finally, the financial needs of the technical field test were satisfied when the MRT gave support and contributed financing.

From 1979 to 1982 Bosch and its partners conducted the ALI technical field test. Equipped vehicles transmitted their destination to roadside computers via loop antennas buried in the roadway. A central computer computed overall traffic flows and provided individual route recommendations, which were then transmitted back to vehicles.

Following the ALI technical field test, Bosch did not pursue additional infrastructure-related projects. Instead, it chose to concentrate exclusively on in-vehicle systems. With its expertise primarily in on-board electronics, Bosch aligned its development strategy to the resources in its possession and ceased pursuing a technical vision requiring a much broader range of expertise. Instead Bosch focused on autonomous in-vehicle systems that required no support from roadside
infrastructure. Thus the technology design resulting from ALI was drastically scaled down to better match the pre-existing division of labor. A similar experience would repeat itself later in the PROMETHEUS Program.
Stage 1 (Research): ALI-SCOUT

Regardless of its outcome, the ALI technical field had brought the ITS technical vision to Germany. However, it remained for others to realize the vision. Although Bosch had been an early pioneer in ITS, it would be Siemens who would develop the technical vision all the way to deployment. Even as ALI was being planned and tested, Siemens developed its own technology for realizing ITS.

The ITS technical vision of an information and route guidance systems was pursued largely by one individual at Siemens, Romuald von Tomkewitsch. A communications engineer employed at Siemens since 1956, von Tomkewitsch occupied the position of Senior Director and Project Leader of Traffic Guidance Systems.

Von Tomkewitsch advanced ITS through the first stage of research. Since the 1970s he had performed research and development on traffic-related electronics, and by 1980 he had deposited Siemens' first patent related to ITS. Already in the early 1980s, working with Volkswagen, von Tomkewitsch had organized a research experiment in vehicle-roadside communications.

Von Tomkewitsch's system vision was called AUTO-SCOUT. Its two defining characteristics were its use of existing traffic control infrastructure and its use of infrared communications between the vehicle and the roadside.

AUTO-SCOUT was an incremental step forward from Siemens' traffic control technology. The
typical Siemens traffic system consisted of a central computer connected to traffic lights throughout a city. The computer modeled traffic conditions and switched the signals in order to ensure smooth traffic flows. Where such systems were installed, most of a city's traffic lights were connected by dedicated cables to a central computer. Significantly, these cables had enough excess capacity to support additional communication between roadside computers and the central computer. The cables represented an available infrastructure for further applications.

AUTO-SCOUT extended this system to the vehicle by using infrared communication beacons mounted on traffic lights. Vehicles would up-load their travel times as they passed through successive intersections, allowing the central computer to model the state of the road network and to compute optimal routes. Roadside computers would down-load individual route guidance recommendations to vehicles, where they would be displayed them on a small screen mounted on the dashboard. By using the vehicles as data collection probes, Siemens avoided the need to install costly traffic sensors in the roadway surface itself. The use of infra-red beacons represented a departure from the buried loop antenna technology used in ERGS, CACS, and ALI. As described below, the system was later renamed "ALI-SCOUT." Figure 6-1 shows the ALI-SCOUT system.
Figure 6-1  ALL-SCOUT System Design and In-Vehicle Display

All-Scout System Interaction

- P: Position Unit
- N: Navigation Unit
- T: Travel-Time Unit
- D: Destination Memory
- Tx: Transmitter
- Rx: Receiver

Beacon Site Controller
- Receives vehicle information
- Communicates to Central
- Connection of up to 16 Beacon Heads

Central Computer
- Executes dynamic routing algorithms
- Updates route recommendations
- Communicates to all beacon controllers
- Maintains all link times

Beacon Head
- Travel and queuing times per link
- Digitized map of beacon area
- Dynamic route recommendations

All-Scout In-Vehicle Graphic Displays

- Follow main road
- Prepare maneuver
- Execute maneuver
- Quick multiple maneuver

- As the crow flies direction to the destination
- Lane recommendation
- Switch to as the crow flies direction in the destination area
- Leave recommended route
Stage 2 (Technical Field Test): LISB

By the mid-1980s Siemens was ready to move to the next stage of development. The firm felt ready to perform a technical field test on the scale of an entire city. This would be LISB (Leit- und Informationssystem Berlin, the Guidance and Information System, Berlin).

Like other ITS advocates attempting a technical field test, Siemens had had to assemble resources on a far larger scale than it had during the previous years of research. Although possessing the necessary expertise, it needed authority to conduct a test in a public area, and it needed financial support to cover the costs.

Siemens would need support from authorities at both the local and national level. Siemens foresaw a city-wide test, probably in Berlin. Therefore the city government and city transportation agency would have to support the proposal. Furthermore, Siemens wanted to develop a system that it could ultimately deploy nation-wide. Therefore, the technical field test would require the support of the MOT. Furthermore, the technical field test would cost millions of dollars, and Siemens hoped to receive public assistance. Therefore the support of the MRT would also be needed.

When mapped onto the sectoral institutions of Germany, the resource demands of LISB defined a set of actors who would have to support the program. To perform LISB, Siemens had to assemble a coalition consisting of the Berlin city government (local authority), the Federal Ministry of Traffic (national authority), and the Federal Ministry of Research and Technology.
Siemens' first step in assembling this coalition was to approach the Senate of Berlin (the city government) with a proposal for a large-scale field test. Berlin had already installed a Siemens traffic control system, and Siemens had numerous ties with the local transportation department. Furthermore, a major field test in Berlin stood a better chance of gaining federal support as part of a long-standing national policy to promote economic activity in a city (then) cut off from the rest of West Germany.

The Berlin Senate welcomed Siemens' proposal. The proposed field test, and the system's possible full deployment later, would possibly increase the efficiency of urban traffic. Just as important, it would provide Berlin with opportunities both to receive federal and industrial investment and to publicize the city name. LISB made good sense for the city, and the Berlin Senate formally approved the proposal in 1984.

Siemens and the Berlin administration next sought support at the federal level. The same federal ministries that participated in the ALI field test were approached for the Berlin test. The Ministry of Traffic and the Ministry of Research and Technology were both requested to support a field test.

These coalition members were demanding. In order to bring the federal ministries into the coalition, Siemens had to give them a voice in the definition of the field test. As in other tests, the

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pre-existing organization of resources shaped development.

Coalition-building and system design interacted over a period of eighteen months. Beginning in 1984 an extensive discussion and negotiation ensued. The MOT in Bonn assembled groups of experts from local government, industry, and universities to review Siemens’ plans. Ultimately, the federal ministries did support the program, but only in exchange for shaping outcomes.

Although Siemens had hoped to perform the field test as the sole industry participant, the MOT and MRT insisted on changes in the composition of participants. The ministries wanted additional industrial partners. The MOT feared that having just one firm might create an anti-competitive situation in which Siemens alone would supply traffic systems. It insisted that other firms participate in the test. The MRT, for its part, would not provide public funding to a large-scale field test involving just one firm. Public assistance of a single firm would indicate excessive favoritism.

Siemens modified the program design and the technology design in order to accommodate the interests of the two ministries. First, it broadened the program to include other industry participants. With its previous experience with ALI, Bosch was eager to join the field test. Although Bosch and Siemens were competitors, they would work together in LISB.

Second, Siemens accepted changes in the technology design. The technology that Siemens originally proposed was its AUTO-SCOUT system. With the addition of Bosch the AUTO-
SCOUT name was changed to ALI-SCOUT, and the in-vehicle display unit for the test was changed to the Bosch unit. Most of the early design remained unchanged, however.

The needs of coalition building also shaped the design of the organization created to oversee LISB. A Steering Committee was created on which all major coalition members could serve. The MOT and the MRT headed the committee, while other members included Siemens and Bosch, some research institutes, and city agencies for research and for traffic. Through the Steering Committee, all players supporting the program could partake in top-level oversight.

Following these changes to the program, the Ministry of Technology (MRT) awarded financial support on 26 September 1985. The Leit- und Informationssystem Berlin (LISB) technical field test was born. It would run from 1985 through 1989 and was expected to cost some $13 million (DM 20.6m). (In fact, by 1991 costs had run up to $15.5 million (DM25.8m).) Funding was shared by public and private sector partners: half was financed the Siemens and Bosch, one quarter from the Technology Ministry, and one quarter from the Berlin Senate.

Siemens had successfully made the transition to the second stage of development, that of technical field test. Working largely alone in previous years, Siemens had developed its system concept through the early stages of research and small-scale tests. With the move to a technical field test, it had had to assemble resources controlled by other players. In assembling the needed coalition, AUTO-SCOUT became ALI-SCOUT. Siemens made the changes necessary to satisfy the partners and to win support for LISB. From 1985 onwards activity focused on defining,

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implementing, and evaluating the field test.

Overseas, by 1985 the Japanese had already completed their six-year CACS technical field test in Tokyo and were beginning to effect the transition to operational tests. In the U.S. no major ITS-related research was underway at the federal level.
Automakers Launch PROMETHEUS

In the early CACS and ALI-SCOUT programs, development began with the creation of a technical vision and moved from there to a search for resources. The history of those programs are stories of ITS advocates pursuing a vision. The other three big ITS programs are somewhat different. In the other two European programs in this chapter and in the U.S. program in the next chapter, resources become available independently of a need for them for ITS development. In those later programs frameworks for funding created opportunities for new initiatives. Perhaps as a result of the ease with which they were launched, those programs were both larger and less successful in achieving their more ambitious goals than the earlier programs.

In the mid-1980s, just as LISB was getting underway, the second and third European ITS programs began. PROMETHEUS and DRIVE were large-scale, cooperative programs with combined public and private participation. In the context of the pan-European EUREKA framework for industrial R&D, European automakers launched the PROMETHEUS Program. PROMETHEUS participants pursued an ambitious vision of a total transportation system through a program of research and early development. The third program, the European Commission's DRIVE Program, was launched in the context of the European Union. Like PROMETHEUS, DRIVE combined an ambitious vision and an experimental research program.

PROMETHEUS and DRIVE both aimed to revolutionize road transport by creating a fully-integrated, pan-European traffic system for information and control. Each program pursued a vision of a total system that would incorporate all aspects of traffic in all the countries and regions
of Europe. And each program pursued that vision through research activities in the laboratory, test track, and occasionally small field test. The two were planned and launched nearly simultaneously and indirectly coordinated with each other.

Compared to LISB, PROMETHEUS and DRIVE were more heavily funded, more ambitious in their technical vision, more research-oriented, and broader in their geographic focus. LISB, however, was much closer to deployment. Romuald von Tomkewitsch at Siemens had brought the AUTO-SCOUT technology through the early development stages some ten years earlier than comparable PROMETHEUS and DRIVE projects. The difficulties that PROMETHEUS and DRIVE participants encountered trying to implement their technologies stands in contrast to the smoother development of Siemens ALI-SCOUT.

**EUREKA Creates an Opportunity**

The story of PROMETHEUS begins with the EUREKA framework for funding. EUREKA was created in 1985 as a pan-European framework by which national governments could support commercial technology development projects. Created in response to Europe's perceived economic lag behind Japan and the U.S., EUREKA was to fund projects that were high-technology, European, and precompetitive.

Unlike MITI or other national technology ministries, EUREKA was a framework with little administrative apparatus. Projects were initiated and managed by consortia of private firms, and public funding was administered through existing national administrations. The only new

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bureaucracy was a Secretariat in Brussels, which would examine and certify proposals as possessing the desirable characteristics. In addition to funding, national governments would provide "supportive measures" to modify institutional barriers to cooperation. These supportive measures might include eliminating obstacles to inter-firm cooperation and opening up public procurement to all European suppliers.

The launch of EUREKA in 1985 created an opportunity for European firms. EUREKA defined a new source of public support for consortia of European firms with pre-competitive research proposals.

Formulation of the technical vision for PROMETHEUS began shortly after the launch of EUREKA. Not surprisingly, the technical vision's funding needs closely matched the funding resources available from EUREKA. Unfortunately, however, the technical vision's needs for authority and expertise bore little relation to what was available. The vision's need for authority did not match existing governance structures and its need for expertise did not match the existing division of labor. Because of this mismatch with sectoral institutions PROMETHEUS ultimately fell short of its goals.
PROMETHEUS: Realizing the Opportunity

EUREKA was intended to stimulate new research initiatives. Shortly after its creation, researchers in automobile companies responded to the opportunity.

In 1985 a group of European automobile researchers set out to formulate a technical vision that satisfied the EUREKA requirements. Their proposal would have to satisfy two basic requirements. First, the proposed technology would have to incorporate advanced technology. Second, the coalition supporting the proposal would have to include firms from throughout Europe. From the final months of 1985 until June of 1986, a vision and a coalition were constituted.

The first steps toward launching PROMETHEUS were taken in the fall of 1985. Discussion had been underway between researchers at the University of Bremen, the Fraunhofer Institute for Information and Data Processing, and Daimler-Benz about the potential to improve traffic and safety through automatic vehicle control. The activities of Siemens had also increased the salience of such ideas. The review of the LISB proposal required by the German Ministry of Traffic had taken place during the previous year, and this helped diffuse the system concept among transportation researchers.

The lead Daimler researcher, Dr. Ferdinand Panik, was a cybernetics engineer who had recently been promoted to a high position in the firm where he had sufficient authority to propose new initiatives. At the end of September 1985--just six months after the first announcement of

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EUREKA -- Panik organized two consecutive weekend retreats to bring together a group of nine Daimler researchers to brainstorm of a new project in transportation. Their idea was a cooperative program for the "redesign of traffic."\textsuperscript{117}

At the weekend retreats they formulated an initial vision of road traffic as a system. This would be a cybernetic traffic system with modeling, sensing, and control capabilities to manage flows on the network. Through the application of electronics and automation technologies, the passive road network would become subject to control and management. This vision would be realized through a program of cooperative research and development. The name of the program was to be PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety.)

To launch PROMETHEUS, Panik first had to convince the Daimler management to support the concept. Not only would the firm have to finance the research, it would also have to cooperate with other companies.

The governance structure of Daimler-Benz, like that of many other German automakers, placed authority for such decisions in a Board of Directors for research and development. Strategic decisions about research were made by this body. Building a coalition in support of PROMETHEUS involved winning the assent of the R&D Boards of each firm in the coalition. Dr. Panik had to first win the assent of the R&D Board at Daimler-Benz and then of other firms.
The time was good for such an initiative, however. Like the rest of the European automobile industry, Daimler-Benz (parent company of the automaker Mercedes-Benz) had enjoyed an extended period of growth and high profitability and possessed the surplus funds to invest in business development. The possibility of EUREKA funding increased the proposal's attractiveness. Within months Panik had formal approval to go ahead with a program of pre-competitive, cooperative technology development.

Even as Panik was winning support within his company, other firms were being recruited to join PROMETHEUS. A coalition was forming. The Daimler researchers approached researchers in other firms, explained the systemic vision of traffic to them, and urged them to join in the cooperative program. This activity went forward throughout the fall of 1985.

The first firms to commit were the electronics and aerospace firms within the Daimler-Benz group. In early December, Dornier and AEG committed to PROMETHEUS. With the post-Cold War decline in defense spending, these firms were keen to develop new civilian markets. German automakers followed shortly thereafter. VW, BMW, and Porsche were approached in turn, and all made initial commitments to the program before the end of 1985. A large number of research institutes also participated. The Fraunhofer Institut for Information and Data Processing, one of the earliest proponents of the cybernetic concept, was only one out of some fifty institutes that ultimately participated in the early stage. By the beginning of 1986, just three months after the first brainstorming sessions, researchers from German automakers, defense firms, and institutes were working together to formulate a vision and a program.

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Coalition-building outside of Germany proceeded almost simultaneously as within Germany. From the beginning Panik and other foresaw cooperation on a pan-European dimension. Indeed, the first public announcement of PROMETHEUS had been at the European Automobile Show in November 1985, where a member of Daimler's R&D Board had invited other automakers to join in a new program. By early 1986 other European automakers became involved. Italian automaker Fiat was the first to join when it attended a planning meeting in the second week of January. In the third week, Peugeot and Renault attended. At the last meeting of January British Leyland was present.\textsuperscript{119}

Thus, by February 1986 the coalition of automaker researchers had broadened far beyond Daimler-Benz. A pan-European coalition of firms had begun cooperating on the redesign of European traffic. Later, in the summer of 1986, Saab and Volvo would also join PROMETHEUS. Ultimately, some fourteen different automobile companies participated.

The coalition-building activities of the German automakers reflected both the incentives and the constraints of EUREKA. First, since the coalition had to extend beyond Germany in order to qualify for pan-European funding, the German automakers had taken their efforts outside their home country. Extending the coalition to French and Italian participants was relatively easy, however, thanks to the prospect of government funding. Unlike Germany, France and Italy guaranteed national funding to projects bearing the EUREKA certification.

Second, in keeping with EUREKA's competitiveness rationale the German automakers avoided

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outreach to non-European firms. This was no small constraint, for among Germany's largest automakers were Ford and Opel (a subsidiary of General Motors.) In building the coalition of firms, the PROMETHEUS promoters duly avoided outreach to Ford and Opel.

Did the opportunity defined by EUREKA bring PROMETHEUS into being? German automakers claimed they would have gone forward with PROMETHEUS even without public funding. Nonetheless, they frankly admitted that the extension of the coalition to France and Italy was greatly facilitated by the incentives in EUREKA. Fiat, Renault, and Peugeot joined the Germans in January 1986 with the certain knowledge that if their proposal was accepted they would win support.

By February 1986 the PROMETHEUS partners were ready to formalize their coalition. In February 1986 the participants signed a Memorandum of Understanding that brought them closer to a formal commitment and that defined a Steering Committee of automakers to govern the program. The PROMETHEUS program as a whole, however, was not incorporated into a legal entity. The coalition-building activities had succeeded.
The PROMETHEUS Technical Vision

The early activities consisted in much more than recognizing an opportunity and assembling a coalition for the EUREKA framework. These activities took place simultaneously with the definition of a PROMETHEUS vision. As the researchers joined together, they collaborated in designing a technical vision of a traffic system.

This technical vision was remarkable in its scope and ambition. From the beginning the PROMETHEUS vision was broad and systematic -- and highly abstract. It was based on a conceptual shift from a network to a system. A network was passive and static; a system was dynamic and capable of being managed. Envisioned as a network, transportation consisted of roads and of vehicles on those roads. Envisioned as a system, transportation consisted of traffic. Traffic was dynamic; associated with it were concepts of throughput, flux, efficiency, control, and optimization.

The reconceptualization of transport rested squarely on the application of new technologies. The basic capabilities of cybernetic control would be realized: sensors would detect the current state of traffic; communication media would collect data at a central location; a central computer would model the traffic network and compute optimal control strategies; control devices such as traffic lights, variable message signs, and in-vehicle information systems would allow for changes to be effected in traffic. Most of these technologies were in electronics, data processing, and computer software.

Road transport could be subject to cybernetic control. The traffic system would be managed in
order to optimize any number of criteria, including throughput, efficiency, environmental impacts, costs, or energy. In the "redesign of traffic" the road network would become a traffic system, and that system would allow for control strategies. Much of the new capabilities would be located within the vehicle, which would be capable of sending and receiving information, informing the driver of traffic conditions and of safety hazards, and computing optimal routes and current location.

Whereas in the past electronics had been applied to the vehicles in a bottom-up, add-on approach, PROMETHEUS would use a top-down planned approach. They would develop a total vision and then plan and implement it. As Panik confidently announced at a later conference, "It's good-bye to the add-on approach." Figure 6-2 illustrates the system approach.

PROMETHEUS planners illustrated their vision with examples of envisioned functions. An "electronic horn" would allow vehicles to warn each other of their presence automatically and thereby increase safety. When approaching intersections, vehicles would only stop if there was vehicle or pedestrian cross traffic. Three-lane roadways could be constructed with the central lane used for overtaking in both directions with inter-vehicle communications preventing head-on collisions. Information on optimal routes and current traffic conditions would assist drivers in achieving their destination.¹²²
System approach: PROMETHEUS

- Smart cars
- Smart traffic

- Smart sensors
- Smart power

PROMETHEUS

"It's goodbye to the 'add-on' approach!"

Automotive electronics

Top-down approach

Bottom-up approach
The justification for this vision was its benefits. However, these benefits were difficult to document. Broad claims of benefits were not lacking: the technology would increase the efficiency of the existing road network; it would improve safety and driving convenience; and it would reduce environmental impacts. However, precise predictions about benefits were rare. The only hard evidence cited by PROMETHEUS proponents -- and cited very frequently -- was that an additional half second of warning time before an incident would reduce accidents by 30 to 50 percent. Otherwise, benefits remained visionary and ephemeral rather than rigorous and predictable.

Although the PROMETHEUS vision was considerably grander than the reality in ALI-SCOUT or CACS, in its basic concepts it embodied the same ITS technical vision. The planners emphasized that the defining characteristic of PROMETHEUS was its systems approach. In the PROMETHEUS vision of the future, the automobile would be one sub-component in the overall road transportation system. Independent components would be linked, and information and control capabilities would be realized.

One characteristic of the PROMETHEUS vision was certain: it closely matched the requirements of EUREKA. The vision and the opportunity fit well. PROMETHEUS advanced all the goals of EUREKA: new commercial products would be developed; a strategic European export industry (automobiles) would be strengthened; innovative information technologies would be applied; and cooperation between European firms would be promoted. EUREKA fit the needs of PROMETHEUS as well. It would provide support for a technology development program whose
goal was to revolutionize road transport.

Approval as a EUREKA Project

By April 1986 the automobile researchers had both joined together in a coalition and produced a common ITS technical vision. Not only had the PROMETHEUS vision been elaborated, a preliminary research program to achieve it had been worked out.\textsuperscript{124} Both the coalition and vision were ready to advance to the next step, formally proposing a EUREKA project.

An application to the EUREKA program was submitted, with the June meeting of the EUREKA Council of Ministers targeted as the date for winning approval. Planning went forward at full speed right up to the June EUREKA conference.

On 30 June 1986 PROMETHEUS's official adoption as a EUREKA project was announced. The program would cost an estimated $700 million and would run for seven years, from 1986 to 1994. It was the largest EUREKA project to date. Fourteen of Europe's automakers had joined in a cooperative program to transform traffic.\textsuperscript{125} Some forty research institutes from around Europe were also participating in the program.\textsuperscript{126}

Thus less than one year after the first weekend brainstorming retreats, a large, pan-European initiative had been created and launched within the EUREKA framework. An institutional opportunity had appeared, a vision was formulated, and a supporting coalition constructed. By spring 1986 all the pieces had been assembled and by June the proposal was accepted.

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That decision marked a transition point. Now the real work would start. The political activities of constructing a common vision and a coherent coalition would give way to more mundane administrative and technical tasks. First, participants had to refine their grand vision and break it down into executable tasks. Second, they had to define the organization of the program.

**Sectoral Institutions**

The ITS technical vision in PROMETHEUS went far beyond the automobile. In order to "redesign traffic" PROMETHEUS planners would have to redesign some aspects of society as well. Furthermore, many of the benefits they proclaimed were societal, such as improved road safety, reduced traffic congestion, and reduced environmental impact.

The system vision also implied a radical transformation of the institutional setting of transport. This was captured in their slogan, "From the product 'car' to the product 'traffic.'" The PROMETHEUS vision would privatize road transport, making traffic a "product." Automakers had unilaterally decided not only to transform traffic but also to convert it from a public good to a market product.

A comparison of the resource needs of PROMETHEUS with the existing organization of resources in Europe reveals that the resource needs of the technical vision did not correspond to existing resources. True, the funding needs of the vision matched the EUREKA framework for funding perfectly. However, the need for authority and, to a lesser degree, expertise would not easily be satisfied by the existing governance structures and division of labor.

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Deployment of a pan-European intelligent transportation required authority for all of Europe’s road transport. Although automakers had the authority to introduce new technology into all of Europe’s vehicles, they had no authority for roads. They lacked some of the authority needed to realize their system.

Not only did the automakers not possess authority over European roads; no actor possessed such authority. European road transport was organized in national jurisdictions, and each country’s transport ministry exercised authority within its frontiers. In order to realize the PROMETHEUS vision of a pan-European system, all the national transport ministries of Europe would have to join the coalition supporting PROMETHEUS.

Although some pan-European transportation organizations existed, they did not possess the appropriate authority. Within the European Commission in Brussels, the Directorate General for Transport (DG-VII) exercised some authority for overall transport policy. However, DG-VII’s concerns and expertise lay in transport regulation and not in infrastructure development. Its lawyers would help little in developing ITS, nor would national ministries recognize its authority to involve itself in such matters. Finally, the European Council of Ministers of Transport (ECMT) defined a forum for policy-makers, but it had little power. To the PROMETHEUS vision of European ITS there corresponded no player with the needed authority.

The need for expertise posed additional problems. Automakers did not possess the expertise in communications and traffic management needed to realize their vision. Much of the needed
expertise lay with firms like Siemens, Bosch, and Heusch Boesefeldt. In order to realize their vision, the automakers would have to bring these additional actors into the supporting coalition.

At the time of PROMETHEUS’ certification as a EUREKA project in 1986 the supporting coalition consisted almost exclusively of automakers and research institutions. It still remained to win the support of transport ministries and communications and traffic engineering firms.

Program Definition

Beginning in October 1986 PROMETHEUS entered “Definition Phase.” Running fourteen months until the end of 1987, the Definition Phase would accomplish three tasks. First, the planners had to broaden participation in the program. Second, they had to design an organizational structure that would define who would participate and how they would cooperate. Third, they would have to make their plan operational by translating the grand vision into research tasks to be executed over the next six years.

The kick-off meeting of the Definition Phase took place in October 1986, just months after the EUREKA approval. The goal of the planners was to launch the full research program at the end of 1987.

Broadening the Coalition

The coalition of researchers assembled by June 1986 was sufficient to win EUREKA approval but was not broad enough to realize the PROMETHEUS vision. With EUREKA approval won, the
next task would be to bring in the missing electronics firms and government agencies.

PROMETHEUS planners had to start nearly from scratch in bringing in public authorities. Unlike Siemens, which had a long history of collaboration with transport ministries in the installation of traffic infrastructure, automakers had a distant and somewhat antagonistic relationship. Indeed, from the ministries' perspective, automakers were part of the problem in road safety, not part of the solution. A speech about the PROMETHEUS program by an official in the German Ministry of Traffic expressed the public sector's attitude: "Up to now, the auto industry must be blamed for supporting the trend towards ever faster cars...", being negatively reflected in rising accident figures. The industry is ignoring or following only reluctantly the demands by the Ministry of Traffic to achieve improved safety at relatively small cost."128 Automakers had a long way to go to realize a partnership with public authorities.

Not only were there few precedents for collaboration, but some features of PROMETHEUS directly antagonized public ministries. Automakers had unilaterally entered the agencies' jurisdiction in pursuing goals of traffic efficiency and safety. Furthermore, the institutional arrangement implied by the technology was anti-government. Privatizing traffic -- going from the "product car" to the "product traffic" -- represented an agenda for reducing the authority of public ministries. This, too, contributed to ministries' lack of enthusiasm for PROMETHEUS. Although not publicly opposing PROMETHEUS, the German Ministry of Traffic did not embrace it either.

The EUREKA framework proved of little use in linking PROMETHEUS with transport
ministries. EUREKA provided relationships with the wrong ministries. In its origins, EUREKA was the product of technology ministries and foreign ministries who negotiated the pan-European agreement and funded the projects. EUREKA's goals were to improve competitiveness in semiconductors, software, computers, lasers, etc. In neither its origins nor its goals did EUREKA relate to transport ministries. As a result, transport ministries did not feel bound by EUREKA's promises of "supportive measures" to ease regulatory and administrative barriers to new commercial technology.

Automakers made two attempts at liaison in order to bring transport ministries into the coalition of PROMETHEUS supporters. First, they defined a liaison body called the PROMETHEUS Council. The PROMETHEUS Council would provide an organizational interface so that government representatives would keep abreast of technological developments and assess changes to transport policy needed to implement systems. The Council would also serve as a forum for government representatives to discuss among themselves their responses to the technologies and transportation scenarios developed within PROMETHEUS. Second, in EUREKA they worked with transport ministries to set up the EUREKA Road Transport Projects Monitoring Group. Again, transport ministry representatives would monitor developments and share information with automakers.

Both bodies failed to make successful connections between PROMETHEUS and transport ministries. The German Ministry of Traffic was particularly unresponsive to the PROMETHEUS Program. Fearing that participation on the PROMETHEUS Council would imply endorsement of
industry's plans, it chose not to participate. Instead, the PROMETHEUS Council attracted support from the ministries of research and industry that created EUREKA. The first chairman of the PROMETHEUS Council was the German Ministry of Research and Technology (MRT).

The EUREKA Road Transport Projects Monitoring Group also yielded poor results. There, transport ministries did send representatives to learn of new developments, but they adopted a passive attitude. They were interested primarily in receiving information about PROMETHEUS rather than participating as partners. With little active participation from public ministries, PROMETHEUS planner found little value in the group, and eventually it was canceled.

By 1987 the failure to bring key ministries into the program became obvious. Speaking at a major PROMETHEUS Symposium the Head of EUREKA suggested that "a second try should be made to establish a representative transport working group within EUREKA..." [emphasis added]\(^{129}\) Automakers' attempts throughout 1986 and 1987 to involved transport ministries had met with little success.

Transport ministries, however, were just one of two groups lacking from the supporting coalition. The technical vision also implied active participation by electronics firms. These were the second group to which the automakers performed outreach.

The experience with electronics firms was just the opposite of the experience with transport ministries. Early on, electronics firms expressed their eagerness to join PROMETHEUS.

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However, the automakers shunned their participation. The automakers decided that only after the Definition Phase at the end of 1987 would they broaden participation to other industries. Electronics and automobile supplier firms would have to wait until the automakers would allow them to enter, and then they would occupy a subordinate role. Despite their need for expertise, automakers shunned partnership with electronics firms.

Siemens was the most obvious candidate for top-level participation: it was a leading German corporation, possessed electronics expertise, and was already setting up the LISB field test. From a technical point of view, its cooperation with the automakers made perfect sense. Yet from a competitive perspective, such cooperation was less attractive. Automakers as a group competed with electronics firms in the market for in-vehicle electronics. When researchers from LISB expressed interest in participating in the program, automakers showed little interest. Like other electronics firms, Siemens would have to wait until after the automakers defined the program before it could participate. Even as transport ministries shunned participation in PROMETHEUS, electronics firms were kept outside of the program until it was fully defined.

Ultimately, the coalition supporting PROMETHEUS at the end of 1987 differed little from the coalition of June 1986. As before, automobile firms and research institutes worked together. The numbers of individuals working on planning did grow: halfway through the Definition Phase, in January 1987, some one hundred and sixty industry researchers, together with an equal number of scientists from independent institutes, were planning a research program. However, participants from the public sector and from the electronics industry remained outside. Transport
ministries chose to keep their distance from the automakers' vision of a traffic system, and electronics firms were not yet allowed to enter.

**Defining A Research Plan**

Perhaps the most important activity in the Definition Phase would be to define the individual tasks and overall research plan to realize the vision. By April 1986 the participants in PROMETHEUS had prepared a program description that summarized much of the vision and began to define the specific content of the program. During 1987 they had to define precisely what they intended to do.

If the ultimate goal of PROMETHEUS was to revolutionize surface transportation, the means chosen were far removed from the goal. The researchers' defined a program that emphasized fundamental research in artificial intelligence, semiconductor design, and communications protocols. Research would seek to advance the frontiers of knowledge in these fields.

An accompanying program of industrial research was more applied. Three cross-company teams performed research in three functionally different areas. The first focused on electronics in the car for autonomous systems with no interaction with the environment; the second focused on systems for vehicle-to-vehicle communications; and the third examined vehicle-to-infrastructure communications.

Independently of this cooperative research conducted within the EUREKA framework, each

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automaker would develop one or more prototype vehicles. These prototype "Demonstrator" vehicles would apply the research results to achieve different kinds of functionality. One Demonstrator, called "ALERT," would sense obstacles, assist drivers to see the road, and monitor blind spots in drivers' field of vision. The technology applied in ALERT included radar, infrared sensing, and projected, "head-up" display of warning signals in the windshield. Another Demonstrator, "ITER," performed functions and used technologies similar to Siemens' LISB system. Vehicles would communicate with roadside information providers to realize vehicle navigation, route guidance, and fleet management. Figure 6-3 shows two of these Demonstrators.131

Although the Demonstrators were closer to market than most PROMETHEUS activities, they were still prototypes for feasibility. As a precompetitive and cooperative program, PROMETHEUS would not result in marketable products. It would develop base technologies and early functional systems to allow for competitive product development towards the "product traffic."

At the end of the Definition Phase the research tasks for PROMETHEUS were published in nine volumes. These volumes listed research "Topics of Research" such as actuators, chip design, communication protocols, and more. At the end of the Definition Phase these Topics of Research would be released to electronics and supply firms who would be encouraged to submit research proposals. Firms could bid knowing that their efforts would be part of a larger program.
Figure 6.3: ITER and ALERT Demonstrator Prototypes

**ITER**

Tasks
- Localisation
- Route guidance
- Viability and general information
- Fleet management

Means
- Digital map
- Beacons
- Cellular telephone
- Sensors

**ALERT**

Tasks
- Warning of obstacle
- Support in poor visibility conditions
- Safety diagnostics
- Safety margins

Means
- Radar
- Ultrasonic
- Infrared
- Electronic imaging
- Head-up display
- Sensors
- Vehicle mission modelling

Image enhancement

Safety area monitoring

Warning of obstacles
Thus in the fourteen months of the Definition Phase, from October 1986 to December 1987, even as they negotiated with ministries and electronics firms the researchers translated the PROMETHEUS vision into detailed research tasks. Working independently in labs at their firms or institutes and meeting frequently in different cities in Europe, the researchers defined the content of the PROMETHEUS Program. During this time they also began work on some of these tasks. However, only in November 1987 would they release the Topic of Research to outside players and begin the full program.

**Governance: Top-Down Planning**

In addition to broadening the coalition and defining the technical content, the Definition Phase also served to decide on the organizational structure of the PROMETHEUS Program. This structure not only defined how groups would cooperate, but also who would control the program and by what means.

Already from the beginning the PROMETHEUS vision implied a top-down planning organization. In the PROMETHEUS vision electronic devices would no longer accumulate in vehicles in an ad hoc basis, but would now be designed within a coherent vision of an overall system. During the Definition Phase the planners defined the PROMETHEUS Organization to give form to this top-down approach.

Figure 6-4 illustrates the PROMETHEUS Organization. At the top of the organization was the Steering Committee, which exercised governing authority over PROMETHEUS as a whole.
Another unit, the PROMETHEUS Council (described earlier) served to make connections with the public sector. Organizational units were also defined for each of the three industrial research streams (PRO-CAR, PRO-ROAD, PRO-NET) and for the four basic research streams (PRO-CHIP, PRO-ART, PRO-COM, and PRO-GEN).

The Steering Committee was the managerial center of PROMETHEUS. It would set technical objectives, defining and revising the goals of the program. It would control time schedules for the development and delivery of systems. It would monitor and manage costs and program spending. And it would review and approve of cooperative arrangements between players.133

In the membership of the Steering Committee the automakers formalized their control over PROMETHEUS. They limited participation on the Steering Committee to just themselves. Opel and Ford were excluded from the program as a result of the competitiveness rationale in the EUREKA framework, and electronics and supply firms were excluded due to their roles as subcontractors. Managerial control rested with the early proponents of the program.
PROMETHUS Organisation

PROMETHUS Council
Administrative and framework support

PROMETHUS Steering Committee
Formulation of technical objectives
Task distribution
Control and exploitation of results

Industry Research

PRO-CAR
Driver assistance by electronic systems

PRO-NET
Vehicle-to-vehicle communications

PRO-ROAD
Vehicle to environment communications

PRO-ART
Methods and systems of artificial intelligence
French/Swedish coordinated

PRO-CHIP
Custom hardware for intelligent processing in vehicles
German coordinated

PRO-COM
Methods and standards for communications
Italian/Swedish coordinated

PRO-GEN
Traffic scenario for assessment and introduction of new systems
British coordinated
A number of explanations were given for the decision to keep governance limited. One reason was that, given the enormity of the program, the mechanics of effective leadership required a small group. Therefore, membership was arbitrarily limited to the automakers who launched the original idea. A related reason was that the structure of PROMETHEUS simply employed established industry procedures in which automakers developed the ideas and then sub-contracted to electronics and supply firms. As an early comprehensive planning document noted, "The procedure selected for the PROMETHEUS programme is exactly the same as is customary in the automobile industry. It is therefore the most efficient way of integrating the large number of other companies into the project." Some critics offered different interpretations. One public official later characterized the attitude of the automakers as, "We are in the driver's seat, so we will tell you what we want, and you just listen."

Although not explicit in the organization design, the Steering Committee also possessed some limited mechanisms for controlling the participants in the program. Through their influence on the distribution of EUREKA funding automakers gained some control. Some national governments effectively delegated funding decisions to the automakers on the Steering Committee. In Germany, for instance, much public funding for research was given to automakers who then funded research institutes. This arrangement gave automakers some levers of control over the research institutes working in the program.

In other countries, however, national funding for research institutes went directly to the institutes. Research institutes in Italy received national funding directly. This denied the Steering Committee

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the use of funding as a management control tool. Thus, the mechanisms by which the members of
the Steering Committee could effectively control the other program participants were not
consistent across all players.

The PROMETHEUS Symposium

The Definition Phase finished with a PROMETHEUS Symposium in Brussels at the end of 1987.
Over seven hundred industry representatives, mostly from the electronics and supply industries,
were invited to the Symposium to learn about the full details of the PROMETHEUS Program.
Speakers from the EUREKA Secretariat, from Daimler-Benz, and from other European
automakers explained the vision, the research tasks, and the program organization to the
attendees. Dr. Ferdinand Panik presented the vision of traffic as a system and emphasized the
market opportunities in vehicle electronics. Hans-Peter Glathe, also from Daimler-Benz,
discussed organizational and legal issues. An entire day was dedicated to presenting the Topics of
Research.

The emerging limits on the program were also acknowledged. The problems with transport
ministries had not been overcome. In his speech at the Brussels Symposium, the Head of
EUREKA noted this shortcoming, saying "it has already become clear from the first deliberations
in this [PROMETHEUS] Council that the commitment of EUREKA research and technology
ministers alone will not suffice... Issues will have to be brought to the attention ... of the national
transport ministries..." Effective cooperation with transport ministries remained to be achieved.

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The composition of the Steering Committee was also formally announced. In presenting the arrangement, Daimler's Glathe hastened to assure the attendees that the PROMETHEUS Organization could still change in the future: "We recommend to keep this organization at least for the starting phase of this joint research programme with new partners. Depending on experience and progress in cooperation a revision of the organization structure will be made." The fact remained, however, that most attendees of the symposium would be under the managerial control of the automakers.

Besides informing those present of decisions already made, the Symposium served to distribute the Topics of Research. The tasks in the nine volumes would be used by participating companies and institutes to craft research proposals for PROMETHEUS. Companies could combine different tasks into research projects and submit them to the Steering Committee. Once their proposals were accepted as PROMETHEUS research projects, the firms would be eligible for national funding. Firms could then work with their national governments to receive assistance. In Germany, for example, public funding supported 40% of industry's costs and 100% of research institutes' costs.

After the Brussels Symposium PROMETHEUS was up and running -- almost. The electronics and supply firms would need some time to review the Topics of Research, formulate proposals, have them reviewed, and then work with their national governments to arrange for financial assistance. Additional months would be consumed. Ultimately, about one hundred proposals were received. The plan developed by the automakers and research institutes had been passed.
to the broader electronics and supply industry who could now join in.

In summary, by 1988 PROMETHEUS was underway. The institutional opportunity created by the new EUREKA framework had been successfully targeted by automobile researchers who launched a program to revolutionize traffic. Following the launch of PROMETHEUS in June 1986, they immediately set out to define a detailed program of research. In the Definition Phase running until the end of 1987 they sought to expand the supporting coalition, to define detailed research tasks, and to create an organizational structure to govern the program.

Even as they finished the Definition Phase, however, weaknesses were apparent. First, their efforts to win the support of government transport ministries had encountered little success, while their unwelcoming attitude toward electronics firms had kept important partners outside of the program. Second, the technical content of the program was far removed from the vision. Their goal was a radical reconceptualization of surface transportation, yet their program consisted of a program of research in basic areas like chip design and artificial intelligence. Finally, the PROMETHEUS Organization formalized the mismatch between participation in management and participation in the program. Only the original automakers proposing PROMETHEUS were allowed on the Steering Committee.

The exclusion of electronics firms and the uneasiness of transport ministries about PROMETHEUS contributed to the launch of a second pan-European program. This was DRIVE, a public-sector program that was complementary to PROMETHEUS. The vision of
road transport as a system received a boost from this additional program.
The European Commission Launches the DRIVE Program

The third European program in transportation-information infrastructure was the European Union's DRIVE Program. In 1988 the European Commission (EC) of the European Union in Brussels launched a program similar to PROMETHEUS called DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe).

DRIVE began as a technology applications program. Although it sought to improve transportation, its fundamental goal was to apply “telematics” technology (a combination of information and telecommunications technologies.) DRIVE applied telematics to transport, while other parallel EC programs applied telematics to health care and libraries.

DRIVE resembled PROMETHEUS in that the opportunity for a program preceded the creation of a vision. Whereas the creation of EUREKA in 1985 led to the launch of PROMETHEUS in 1986, the launch of a “telematics directorate” in the EC led to the launch of DRIVE in 1988.

DG-XIII: The Telematics Directorate

The European Union is a pan-European government with a strong central bureaucracy, the European Commission (EC). Located in Brussels, the EC possesses capabilities and responsibilities in areas as transport, economic development, energy, and education.

In the early years of the 1980s entrepreneurial administrators in the EC succeeded in launching two development programs in information and telecommunications technology. ESPRIT

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(European Strategic Programme for Research and Development in Information Technology) was a cooperative program for precompetitive R&D by industry, research institutes, and universities. Running from 1984 to 1988, the policy goal of ESPRIT was to promote the European information industry, while the means were to subsidize R&D. The second program, RACE (R&D in Advanced Communications Technologies in Europe), trailed ESPRIT by just a few years. Whereas ESPRIT focused on base technologies in informatics, RACE focused on communications research such as system designs, optics, design tools, and communication software. RACE broadened the EC's policy activity to include communication as well as information. Together, information and communication technologies came to be known as "telematics."

ESPRIT and RACE led to the creation of an organization within the EC for promoting information technology and industry. This was the new Directorate General (DG) XIII for Telecommunications, Information Industries, and Innovation. DG-XIII became a champion for EC policy initiatives in telematics. With strong political support from leadership in the Union, entrepreneurial management in its programs, major budgets for research, and growing expertise in program management, in the late 1980s DG-XIII was looking for new areas of telematics policy.

DG-XIII and EUREKA resembled each other, in that each sought to promote commercial technology development. However, DG-XIII had an administrative staff, whereas EUREKA delegated administration to the parties proposing a new program.
The ITS Technical Vision

The visionary behind both DG-XIII's early activities in telematics and its move into what would be called "transport telematics" was Roland Huber. Huber was one of the early proponents of the ESPRIT and RACE programs, and he now sought to apply the results in a series of telematics applications programs. One potential application area was road transport, and others included health care, distance learning, libraries, and rural areas.\textsuperscript{142} The evolution from ESPRIT and RACE into more applications-oriented programs reflected Huber's vision of applying information technology to all sectors of European society.

From the beginning DG-XIII recognized that any program in transport telematics would require collaboration with transportation organizations. Although DG-XIII possessed both expertise and funding, formal authority for road transport lay with another Directorate.

As noted earlier, the EC's Directorate General for Transport (DG-VII) was a regulatory directorate with responsibility harmonizing regulations. DG-VII supported very few research activities and did not promote the application of new technologies. Thus DG-XIII's technical vision held little appeal for DG-VII.

DG-XIII did succeed in overcoming DG-VII's disinterest enough to win its participation in a planning exercise. In anticipation of defining something called "transport telematics," DG-XIII formed a study group to investigate possible applications. Both Directorates oversaw this activity, which ran from late 1985 into the summer of 1986.\textsuperscript{143} Funded by DG-XIII and prepared

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by outside consultants, it sought areas to apply DG-XIII's telematics technology to the transport sector.

To DG-XIII the manner in which telematics technology was applied was not terribly important. What mattered was that new capabilities developed in earlier programs be put to use. Initially planners thought that the telematics would be used to create in-vehicle information consoles to improve driving safety. In the course of the exercise, however, the vision of safety was expanded to include efficiency. The technical vision that emerged from the early activity included not only vehicle accident avoidance, but also communications and traffic control on urban streets and freeways. Figure 6-5 shows the management structure together with some of the topics examined.144

Although the product of the planning activity was more of a sketch than a full technical vision, it provided the basis for proposing a program. Publicly presented at a conference in Brussels in September 1986, the plan outlined a research program in transport telematics and noted the need for substantial funding.

A vision of transport telematics now existed. It remained for DG-XIII to launch a program to realize the vision.
Planning Exercise Management Structure

DG XIII and DG VII

Management Contractors

Study 1.1
Vehicle Accident Avoidance
Consultronique (France)

Study 2.1
Communication and Navigation
Blaupunkt and University of Padeborn (FR Germany)

Study 3.1
Urban Traffic Control for Road Safety
GEC Traffic Automation (UK)

Study 3.2
Motorway Traffic Control for Road Safety
Autostrade (Italy)
Program Launch

No sooner had DG-XIII defined the DRIVE vision, however, than it ran into a series of setbacks. First, the opportunity for a follow-on program was jeopardized by the launch of PROMETHEUS. PROMETHEUS had been approved as a EUREKA project in June 1986, just three months earlier, and the same national ministries of research and industry with which DG-XIII traditionally collaborated were providing the EUREKA funding for PROMETHEUS. The redundancy was obvious: both DRIVE and PROMETHEUS sought to create complete information-transportation systems, developing everything from in-vehicle devices to infrastructure. With both programs based on a similar vision, DRIVE appeared unnecessary. In the fall of 1986, shortly after the meeting to present the plan, work on DRIVE slowed and nearly stopped.\footnote{143}

Planners in DG-XIII worked with researchers in the automobile industry to try to save DRIVE. Fortunately for them, their common vision was so broad that both programs could be accommodated. Furthermore, since DRIVE was a public program and PROMETHEUS was an industry program, they could divide activities between them in a complementary manner. DRIVE could focus on infrastructure development, while PROMETHEUS could focus on vehicle systems.

The respective roles of PROMETHEUS and DRIVE were settled in a joint workshop held in April 1987 in Brussels. There, researchers from the two programs met together for three days and defined their respective areas of activity. Overlapping areas of research were identified and reorganized in order to avoid duplication. Because both programs were still in their infancy, and

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because they were at approximately the same state of development, coordination between them could be achieved without generating conflict. A project for defining digital map standards was transferred from PROMETHEUS to DRIVE, since standard-setting was a more public sector function.\textsuperscript{146} DRIVE's early emphasis on in-vehicle displays was likewise reduced, since commercial firms saw this as a product. As a result of this activity, political support in the Commission for a DG-XIII program in transport telematics was reconstituted.

Even as DG-XIII successfully managed its relationship with the automakers, however, its relationship with the transport directorate, DG-VII, grew difficult. Although the two directorates had collaborated in the planning exercise, this had reflected more of a personal interest by some individuals within DG-VII than a policy commitment by the transport directorate.\textsuperscript{147} Ultimately, the leading DRIVE champion in DG-VII, Mr. Fotis Karamitsos, had to formally transfer from DG-VII to DG-XIII. Following the resumption of political support for DRIVE in early 1987, DG-VII's slight interest in transport telematics disappeared altogether.

Concluding that the proposed program reflected too much of a technology-push approach, DG-VII stopped any further collaboration. The planners working on transport telematics within DG-VII were given to understand that they could continue their activities, but that these no longer enjoyed high-level support.\textsuperscript{148}

DG-XIII decided to launch DRIVE even without DG-VII. True, DG-VII figured prominently in its vision of a pan-European intelligent infrastructure. However, the coalition necessary to launch
the DRIVE and the coalition needed to ultimately realize the DRIVE vision were not identical. DG-XIII felt it could assemble the necessary coalition to launch a follow-on to ESPRIT and RACE, even without the transport directorate. Later, it would have to expand the coalition.

In July 1987 DG-XIII formally proposed a Community R&D Programme called DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). During the following twelve months the proposal was extensively reviewed by both the European Parliament, consisting of popularly elected representatives, and the Council of Ministers, consisting of representatives of national governments. In June 1988 DRIVE was formally approved as an EU program.

In the year between the proposal for DRIVE in 1987 and its adoption as policy in 1988, DG-XIII created a detailed Workplan. The Workplan was the "bible" of the program, defining the objectives, research tasks, and management structures of the program. By the time DRIVE was formally approved in June 1988, the Workplan was largely ready. It defined two groups of R&D activities. The first area of R&D was traffic management. Research here focused on vehicle-roadside communications, traffic optimization algorithms, fleet management, and other techniques for utilizing information to better manage facilities. The second was road safety. Research here focused on new approaches for sensing obstacles, avoiding collisions, and monitoring driver behavior.

In July 1988 DG-XIII issued a call for research proposals and invited firms to bid on the tasks in the Workplan. Firms, research institutes, and public agencies began forming consortia to propose
research projects. DRIVE was underway. DG-XIII had defined and launched a follow-on program to ESPRIT and RACE that would implement telematics technology in the transport sector.

In mid-1988 other programs around the world were in various stages of development. In Japan, both RACS and AMTICS were conducting stage-three field tests to integrate ITS into operating transportation agencies. In Germany, Siemens’ LISB technical field test in Berlin was unfolding. PROMETHEUS was only slightly ahead of DRIVE as automakers worked to integrate electronics companies into their program following the Definition Phase. In the U.S. a small group of researchers calling themselves “Mobility 2000” was meeting informally to draft a proposal for a U.S. ITS program.
Technical Vision and Sectoral Institutions

In the mutual adaptation between DRIVE and PROMETHEUS, DRIVE had implicitly adopted that other program's technical vision. Like PROMETHEUS, DRIVE sought to develop a pan-European traffic and vehicle control system. Both programs pursued the ITS technical vision of a system in which vehicles were joined by a communication link to the roadside. This received less articulation in the Workplan than it had in the PROMETHEUS documents. Yet to the extent that the many tasks in the Workplan had coherence, it lay in the vision of a vehicle-roadside system for all of Europe.

Pursuing the same technical vision as other programs, DRIVE needed three kinds of resources: expertise, funding, and authority. The expertise needed by DRIVE existed, but was scattered throughout much of Europe. In drafting the Workplan DG-XIII had assembled a technical experts group that included representatives of national transport ministries, industry, and independent research institutes. DG-XIII had little difficulty assembling the expertise, because the directorate already had extensive experience working with the European research community.

DRIVE also needed funding to realize its ambitious vision. Although the funding for an entire European system would be very large, funding for stage-one research would be much less. DG-XIII approached transport telematics like it had approached RACE and ESPRIT, focusing almost exclusively on laboratory research. Activities in this stage would consist of small-scale experiments performed by just a few researchers. Since no DRIVE project involved large field tests like those in LISB or CACS, the required budget was much smaller than what would be

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needed for deployment.

DRIVE funding was set at 70 million ECU (European Currency Units, worth slightly more than one U.S. dollar), to be used over a period of three years. These funds would pay for one-half the costs of industry consortia performing transport telematics research.

The framework for funding from which DRIVE received support was the EU’s Framework Program. This funded all research activities in the EU. The Framework Program introduced additional players into the ITS development process, however. Framework funding decisions required approval by the European Council, a body representing the member states of the EU. After program launch, member states were represented by an oversight group called the DRIVE Management Committee. Through their influence in the DRIVE Management Committee, member states’ distributional concerns entered the development process. Thus the framework for funding used to fund DRIVE introduced distributional concerns into the program.

The third resource needed to realize the ITS vision was authority. Here the ITS proponents in DG-XIII faced two problems. First, nothing in DG-XIII’s charter authorized it to engage in transport policy, and very few DRIVE participants came from transport agencies. Second, as noted in the earlier discussion of PROMETHEUS, no pan-European transport authority even existed. This was like Japan, only that instead of transport authority being shared by two national agencies, in Europe it was shared by over a dozen. Assembling the necessary authority from a large group of independent agencies that had expressed little interest in ITS would be a major
challenge for DRIVE.

Thus, the ITS proponents in DRIVE could assemble enough resources to begin with stage-one development. The resource needs of later stages, however, were likely to pose future problems.

With the launch of DRIVE there were a total of four ITS development programs in the world. Three of these were in Europe and one was in Japan. Two development programs, that of Siemens and that of the Japanese ministries, closely pursued the original ITS technical vision from ERGS. With the LISB field test advancing toward evaluation in 1989, Siemens had nearly completed the second stage of development. With RACS and AMTICS both nearly finished, the Japanese were well into the third stage of development. PROMETHEUS and DRIVE, on the other hand, were considerably less advanced. Both programs focused on stage-one research.

Over the next five years each program had very different experiences. Not surprisingly, PROMETHEUS and DRIVE encountered the greatest difficulties realizing their visions. In adjusting to the available resources, they altered their programs considerably.
DRIVE Program Execution

Published in July 1988, the DRIVE Workplan had defined the areas of research where firms could bid for DRIVE funding. By January 1989 seventy-two projects were selected, and DRIVE was underway. The program would run for three years, from 1989 until 1992.

DRIVE projects covered a wide range of activities. Many projects focused on computer models to simulate traffic and to optimize flows. Others focused on driver behavior, systems to monitor driving, and man-machine interfaces. Another set of projects investigated the feasibility of microwave, cellular telephone, and satellite communications.

The unity of the many different activities was not self-evident. There were studies in mathematical models for traffic simulation, bus scheduling, and fleet management. Other studies looked at base technologies in computer vision, artificial intelligence, and data transmission. Still other examined such topical areas as pedestrian safety as intersections, accident data collection, and vulnerable road users. Clearly, all topics consisted of the application of telematics to transport, but within that unifying vision a collection of very diverse projects were defined.

Two features of all projects reflected the effects of sectoral institutions. First, DRIVE was fragmented into many small projects. The framework for funding for DRIVE had subjected the program to distributional requirements. Before projects could be officially supported they had to be approved by the DRIVE Management Committee, where they were examined for distributional equity among member states. Individual projects also consisted of many partners, as proposers

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added partners to improve their political attractiveness. As a result of this DRIVE had to spread its limited funds among many projects and many actors. With ECU 70 million shared among 72 projects over three years, each project could received only about ECU 300,000 per year (approximately $300,000). That could fund only small laboratory projects.

Second, projects were research-oriented. In keeping with DG-XIII's mission, DRIVE focused on technological research rather than end-user benefits or on-site deployment. Deployment had barely figured in DG-XIII's earlier RACE and ESPRIT programs, in which new technologies could simply be handed off to private firms for deployment in products. This research emphasis continued in DRIVE.

The tendency to perform research was exacerbated by DG-VII's indifference to ITS. With little support or participation by transportation agencies, the formulation of applied research was difficult. DRIVE ran independently of the transport directorate, and its grandiose vision of an information society went ignored by transportation planners, even though the technology was supposed to benefit transport. As a result research began with little attention given to its feasibility in an applied setting. For instance, some DRIVE research focused on the technologies of road pricing. However, this work did not include investigation of the social desirability and political implications of road pricing. Even if the technology worked perfectly, the more significant issues of its deployment remained unexamined. This neglect of deployment issues in technical research characterized many DRIVE projects.149

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Over the next three years, each of the seventy-two projects in DRIVE pursued its goals and sought to deliver its promised research products. Researchers worked on location at their home organizations, gathering at six-week intervals to present their work and learn of others' activities. In the three years of the program's duration, from 1989 through 1991, a broad array of research and development projects were executed.

External auditors reviewed the program in 1989 and again in 1992. Auditors gave an overall favorable evaluation, concluding that the program was fully justified. However, the auditors also identified weaknesses. Projects were too small. They were too scattered. And they were too far removed from deployment. Auditors recommended that DRIVE should seek to implement large-scale pilot projects, even if that would reduce the overall number of projects. However, they did not acknowledge the underlying institutional forces causing such fragmentation. The effects of the sectoral institutions were recognized, even if the causes were not.

**Organization**

Policy-makers in DG-XIII knew the difficulties confronting their program. DRIVE needed internal integration and external coordination. Internal to DRIVE, the myriad research projects needed horizontal integration among themselves. External to DRIVE, projects needed coordination with related activities in PROMETHEUS and with the transportation agencies who would one day implement ITS.

DG-XIII itself assumed only limited responsibility for integration and coordination. A "DRIVE
Office” in DG-XIII monitored program spending and ensured that research teams met milestones. However, detailed technical coordination of the many research tasks fell outside DG-XIII’s capabilities. The definition of a coordinating office to manage cross-cutting topics was left as a Workplan task open to bids.

The consortium that submitted the winning proposal for this task was led by Daimler-Benz. Together with other automakers from PROMETHEUS, Daimler proposed the System Engineering and Consensus Formation Office (SECFO). SECFO perform internal integration and external coordination.

System engineering and consensus formation were in many respects the same thing. One term was technical and the other was social, but they referred to a single socio-technical system. Interconnection of machines required consensus among people. The System Engineering and Consensus Formation Office (SECFO) would simultaneously address both the technical and social aspects of system design.

Whereas most DRIVE projects focused on components, the SECFO project sought to define the system. It would specify both the functions that an overall system would perform and the technical standards by which individual system components would be linked. In addition, it would serve as a liaison to outside actors, including transportation agencies who would ultimately implement the system. All DRIVE project staff would attend regular "concertation meetings" in order to share the emerging results of their work, and SECFO staff would monitor these meeting

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to identify any incompatibilities. If so, they would work with the projects to share information and hopefully resolve divergences. Acting more proactively, the SECFO staff would also try to synthesize emerging research results into common system specifications. Finally, the SECFO staff would serve as liaison with wider European authorities to set standards and to promote deployment. Figure 6-6 shows the information flows connected to SECFO.151

The SECFO proposal was the fruit of behind-the-scenes negotiations between Huber and Karamitsos in DG-XIII and Panik and Glathe in PROMETHEUS. DRIVE and PROMETHEUS needed stable mechanisms for communicating and reaching common agreements. Already during 1987, as DRIVE performed its planning process and PROMETHEUS went through its Definition Phase, the leadership of the two programs had interacted frequently. As DRIVE got underway in the fall of 1988, Panik, Huber, and others in DRIVE and PROMETHEUS agreed on SECFO as an inter-program coordination mechanism.

In the three years of its life, from 1989 to 1992, SECFO struggled to perform the tasks assigned to it. The staff successfully worked with DRIVE projects to promote a European-wide standard frequency for electronic toll collection. This would help ensure compatibility of in-vehicle devices and roadside equipment throughout Europe. SECFO also created deployment tools. By July 1990 SECFO developed a near-term scenario for a European transportation information infrastructure which could serve as a common reference for different groups performing more focused research.
Figure 6.6: Information Flows For System Engineering and Consensus Formation Office (SECFO)
What became increasingly obvious, however, was that SECFO was the recipient of intractable problems rather than an appropriate solution. Although SECFO's responsibilities included the problem areas, its design proved inadequate to perform them.

SECFO could not accomplish system engineering and consensus formation because it lacked both power and legitimacy. Created as a DRIVE project, it was on an equal status with other projects. SECFO had no means to enforce its vision of a system, nor did other groups necessarily accept SECFO's vision as authoritative. Furthermore, its small membership provided no legitimate basis for making decisions on behalf of all participants. Consisting of automakers and a few other players such as Siemens and Philips, it could not claim to represent all participants as a whole. Its vision was simply the SECFO vision, not the vision of the European transport telematics community.

Many problems of SECFO went beyond organizational design, however. Some tasks were arguably impossible to perform. On one side, the European Commission looked to SECFO for definitive statements of the consensual position of automakers on various issues. But frequently such consensus did not exist; even within the PROMETHEUS Steering Committee opinions often varied. For example, no industrial consensus existed on whether DRIVE should promote roadside beacons (with local communications capabilities) or cellular systems (for area-wide communications with vehicles). SECFO could not deliver consensus on behalf of powerful players with divergent views. SECFO suffered from similarly unrealistic expectations from European automakers. They expected that SECFO would influence laws for deployment, enforce

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lagging projects, and actively shape standards. Such expectations were completely unrealistic, however, for many of these were political issues.\textsuperscript{152}

For all these tasks, SECFO was inappropriate. The staff could make expert decisions, but they could neither voice the consensus of broad groups of participants nor push any participants to behave as others wanted. A small group of experts could not effectively perform system engineering and consensus formation.

Thus it was no surprise that the DRIVE audit of 1992 noted a neglect of system integration and deployment. These were the issues for SECFO, but it lacked the power and legitimacy to overcome what may have been insoluble problems.

Expanding the Supporting Coalition

The basic problem in DRIVE was that its technical vision required a much broader supporting coalition than the set of actors that launched it. DRIVE was particularly weak in deployment because of the low participation by transportation agencies.

DRIVE might develop new technologies, but it could not relate them to their applications. For example, researchers might develop devices for short-range vehicle-roadside communications, and these might transmit sufficient data to allow for electronic payments. This in turn might enable road pricing, in which drivers would be charged for driving on roads. However, road pricing involved many more issues than just technology; it had broad policy implications for taxation,

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privacy, local politics, and much more. Without cooperation between technologists and policy-makers in the development of such technology, their deployment would be impossible. Yet most DRIVE projects funded researchers in laboratories who worked independently of any transportation agencies. The results of such research risked never achieving deployment.

Huber and Karamitsos of DG-XIII were aware of the constraints shaping the program and sought to overcome them. During the three years of DRIVE's execution, they worked to connect DRIVE research to the transportation organizations that would hopefully deploy the technology. To do this they had to overcome the boundaries within the European transportation community and to broaden DRIVE's supporting coalition.

In the course of DRIVE they pursued a variety of strategies to make the technology-transportation link. The first of these was the creation of SECFO. SECFO achieved some successes, but the problems of integration and deployment could not be solved by technical experts.

DG-XIII's second strategy for overcoming institutional barriers involved the use of funding. The Directorate would try to win support by paying for technical field tests itself. If it could subsidize field tests like it subsidized research, it would easily win over transportation organizations. This strategy had already proven itself in Japan, where MITI had overcome the National Police Agency's indifference by funding its participation in CACS. Even as DRIVE was underway, therefore, DG-XIII staff sought funding with which to attract the support of transportation
However, DG-XIII could not acquire additional funds through the Framework Program that paid for DRIVE. No additional resources were available here. As an alternative strategy it tried to adapt existing frameworks for funding to the needs of DRIVE. One existing funding mechanism was the EC's Structural Funds for regional development. The Structural Funds provided support to the less developed regions of Europe, particularly Spain, Portugal, Greece, and southern Italy, to accelerate their economic development. The sums distributed here were substantial: in 1992 Structural Funds accounted for 27% of the entire EC budget (some $19 billion). Structural funds were one of the few mechanisms the EC could use for subsidizing development, so DRIVE managers sought to obtain resources here for field tests. Granted, it meant that systems would be implemented in regions that had perhaps the least need for them. Cities like Athens or Lisbon would serve as the vanguard for deployment. That was the only option, however. During the execution of DRIVE, work began to gain access to some of these funds. Ultimately, these efforts were to bear fruit as funds were obtained for field tests in a follow-on to DRIVE.

A third strategy was even more ambitious. This involved redesigning European institutions to gain increased authority and funding for telematics deployment.

During the execution of DRIVE, the Maastricht Treaty on European Union was negotiated. This treaty redefined the basic terms of the European Union, presenting an opportunity to modify EC institutions in a manner that would empower them to undertake deployment. In the Maastricht
Treaty, DG-XIII and other Directorates sought to increase their authority for infrastructure deployment and to win powerful financial tools to achieve this.

The concept by which the EC sought to increase its authority in the Maastricht Treaty was the Trans-European Network (TEN). As ultimately defined in the Treaty, TEN's were networks in telecommunications, transportation, and energy. These networks were bigger than any single nation and, therefore, required European-wide governance in order to assure smooth interconnectivity across borders. Three different EC Directorates defined TEN's that would increase their jurisdiction. For DG-XIII, there was the trans-European Network in telecommunications, for DG-VII the relevant TENs were in air, sea, road, and rail transport, and for the energy directorate, networks in electricity and gas. By including the definition of the Trans-European Network in the Maastricht Treaty, the different EC Directorates increased their authority for deployment.

This strategy did not succeed as well as hoped, however. Although the Maastricht Treaty supported the concept of the TENs, it did not authorize funding for them. When signed by the representatives of the various European member states, the treaty contained only three weak policy tools for supporting the networks. The EC could perform feasibility studies; it could pay for interest rebates; and it could provide bank guarantees. Authority to subsidize the cost of networks would remain at the national level.

The fourth and final strategy to connect DRIVE's technology to organizations in the transport

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sector was to educate road transport policy-makers. If they could be won over to the ITS vision, they might support development themselves. The mechanism for this was a forum where policy-makers would learn about transport telematics and hopefully commit to supporting deployment.

DRIVE managers created the DRIVE Infrastructure Group (DRIG) in April 1989, just months after the launch of DRIVE itself. DRIG’s purpose was to identify sites for future demonstration projects for DRIVE and to recommend priorities for funding. The participants came from national, regional, and local transportation administrations who would someday implement the technology. In 1990 and again in 1992, DRIG published reports identifying deployment cities in urban areas and inter-urban corridors.

However, DRIG’s reports did not lead to action. Committee members did not make commitments. Although coming from transportation authorities, the members served in a personal capacity and not as official representatives of those agencies. Their role, again, was that of experts rather than policy-makers. In this case, the strategy of using a committee to win support of policy-makers did not succeed.

A second high-level committee did result in success, however. In early 1989 DG-XIII assembled the Strategic Consultative Committee (SCC), a group of fourteen high-level representatives of European industry associations and major firms. The SCC considered the key issue facing DRIVE: how to go from basic and application-oriented research to on-site field tests and full-scale applications. To give the committee high visibility, Huber recruited as its leader Dr.
Umberto Agnelli, one of the owner-managers of Fiat. Other members included the President of Volvo, the Chairman of the Spanish Telefonica Sistemas, and a member of the Board of Bosch. These individuals occupied positions of power and responsibility that would allow them to make policy-level decisions for their firms.

Like the DRIG group, SCC issued a final study. In its report of June 1990 the SCC defined ten "functions" to move technology out of the laboratory and into the field. Some of these were technical, such as the need for system engineering, but most dealt with the legal, political, and financial aspects of deployment. For instance, there had to be an analysis of the current need for this technology to see where it would really contribute to improving transport. An analysis of legislative requirements was also necessary to anticipate possible legal barriers to deployment. Financing schemes would have to be examined, to see who would pay for deployment. Field tests would have to be designed and run, and final deployment anticipated. Figure 6-7 shows the ten functions and their interrelationships.\textsuperscript{156}

More importantly, the SCC recommended the creation of a new body to unite all groups with authority for a pan-European ITS deployment. This organization would serve as a single European forum for planning the deployment of transport telematics. Its scope would be pan-European, and its membership would include all actors involved in the development and deployment of ITS. It would fill the gap in the governance structure of European transport, defining the single body with authority corresponding to the ITS technical vision. (The new organization, ERTICO, is described below.)

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The participants in the SCC would themselves launch the new implementing organization.

Although the details were not worked out by the time of their final report, the SCC's planning activity had led to a commitment to action by industry players. At least a subset of the powerful players in the European transport sector had now committed to moving towards deployment.
Figure 6.7: Strategic Consultative Committee's Ten Steps to Deployment
In summary, even as researchers executed their tasks and SECFO struggled to achieve consensus, DG-XIII actively worked to overcome the institutional barriers still confronting DRIVE after its launch. The four strategies for navigating institutions resulted in different degrees of success. The expertist approach in SECFO succeeded little. The strategy of buying support succeeded only slightly better, mostly because DG-XIII could not acquire the large funds needed to implement its technology. A third strategy of gaining deployment authority through the definition of Trans-European Networks fell short of its goal. However, the fourth strategy of educating and winning over senior representatives of important organizations yielded concrete results. Industry supported transport telematics by creating the ERTICO organization for deployment.

**ERTICO**

The European Road Transport Telematics Implementation Co-ordination Organisation (ERTICO) was incorporated in November 1991. ERTICO would succeed SECFO as the locus of activity for system engineering, consensus-building, and deployment in DRIVE.\(^{157}\) Transport telematics had moved beyond being a research program within DG-XIII and had now won commitment from a collection of transportation operators throughout Europe. ERTICO was a substantive, if imperfect, step towards connecting technology research with transportation decision-makers.

In theory, ERTICO would serve as the pan-European institution for implementing transport telematics. DG-VII, the nearest existing organization to perform this role, possessed little interest in ITS, and the various national ministries and industries were too fragmented to implement a single system. Once joined together in ERTICO at the European level, however, all the relevant

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players would be able to plan and coordinate implementation together.

ERTICO would perform many of the same functions originally assigned to SECFO. First, ERTICO would promote cooperation within industry to promote shared R&D and to define the standards needed for large markets. Second, it would promote cooperation between the public and private sectors for mutual planning of systems. It would monitor on-going developments overseas and throughout Europe and diffuse the information among European participants.

If ERTICO's functions resembled those of SECFO, the design of the organization was quite different. First, unlike SECFO, ERTICO was not created as a project within DRIVE. Instead, ERTICO was an autonomous organization incorporated as a non-profit corporation. It might be paid by the EC to execute projects within DRIVE, but it was a legally independent entity. In theory at least, ERTICO was the entity that would pick up the results of DG-XIII's research efforts and implement them in its member organizations.

Another difference was in its membership. Whereas SECFO consisted of a small group of experts, the individuals in ERTICO were from higher positions and were from a larger number of firms. Strategic issues of funding, cooperation, and strategy were now being considered by representatives with the power to make such decisions. Furthermore, with more organizations involved, common decisions made in ERTICO had greater legitimacy as representative of all interested parties. Figure 6-8 shows the composition of ERTICO's intended membership and its relationships with outside organizations.158

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Figure 6-8: ERTICO's Membership and Outside Relationships
Although ERTICO's membership numbered just fourteen organizations when founded in 1991, its membership grew rapidly. By June 1992, it had twenty-three members, and by mid-1994 its membership numbered thirty-six. Of those thirty-six members, two thirds came from such industrial firms as Renault, Bosch, Fiat, Daimler-Benz, Ford, France Telecom, and Philips. The remaining one-third came largely from national Ministries of Transport and associations of transport providers. The social composition of ERTICO increasingly approached the social composition of the transport telematics vision. The combined authority of all members approached the pan-European authority needed for ITS deployment.

Yet ERTICO had not overcome all the problems in SECFO. The reality of ERTICO did not quite fulfill the aspirations of its design. First, many members were still high-level researchers, not policy-makers responsible for deployment. They could commit to research but not to deployment. National transport ministries sent researchers to represent them and carefully avoided any policy commitment to ITS. However, even some industrial players such as Philips sent researchers. One PROMETHEUS participant commented, ERTICO members could not yet speak on behalf of their corporations as a whole only of their research departments. Despite its name as an implementation organization, ERTICO's membership still had a strong research bias.

Second, the membership did not yet fully represent all sectors. Although ministries from the UK, France, and the Netherlands had joined, that left many outside. Most notably, the German Ministry of Transport refused to join. The reason they gave was that as a public bureaucracy, they could not join an organization whose policies might conflict with the German Parliament.
More significant was the German Ministry’s continued skepticism about the benefits of transport telematics to contribute significantly to its mission. Either way, ERTICO had not overcome the split between enthusiastic industry supporters and indifferent transportation authorities.

In the first three years of its existence, from 1992 through 1994, ERTICO provided ambiguous results. Its membership grew, but not spectacularly, going from fourteen to thirty-six organizations. Most of its work was in the context of DG-XIII’s continuation of the DRIVE program, where it arranged concertation meetings and promoted standards-setting. It also initiated some contacts with DG-VII, studying traffic management on the Trans-European Road Network defined in the Maastricht Treaty.

The problems of implementation remained, however. Huber’s strategy of creating the Strategic Consultative Committee had succeeded in winning commitments, and ERTICO was a better-designed version of SECFO. ERTICO’s design would allow it to develop into a high-level representational forum for implementation. However, by 1994 it still had not achieved this goal. The full coalition corresponding to the transport telematics vision had not been assembled.

**DRIVE II**

In addition to managing DRIVE and to seeking to bridge institutional barriers, DG-XIII also had to plan a follow-on program to DRIVE. “DRIVE II” would succeed the original “DRIVE I” program which was to end in 1992. DRIVE II would continue research and would begin applying the results in real world transportation sites.

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Internal audits of DRIVE I made three recommendations for a follow-on program. First, there should be such a follow-on. Transport telematics held promise and merited continued investment by the EC. Second, there should be greater coherence in the program. The program was fragmented into too many small, independent research activities. Third, there should be large demonstration projects to test the technology in real world conditions. The program needed greater depth, even if that was obtained at the cost of reduced breadth; a few large demonstration projects would be preferable to many small ones. This last recommendation for concentrated funding reflected the need for ITS development to advance to stage-two technical field test.

DRIVE II could only imperfectly implement these recommendations. Launching a follow-on program was politically feasible, so the first recommendation was followed. The second recommendation, to achieve greater coherence, was largely addressed by ERTICO, although whether that organization could integrate the many activities remained uncertain. The third recommendation proved completely infeasible, however. Funding a small number of large-scale tests ran contrary to distributive forces. DRIVE II might fund field tests, but they had to be distributed among all the member states of the European Union. The funding framework was controlled by the EU member states, who required distributive fairness in program spending.

In June 1991 DRIVE II was formally launched by the European Union. DRIVE II funding was greater than the previous program, but was spread more thinly. DRIVE I funding had amounted to $72 million and had been spread over seventy-two projects running three years. DRIVE II funding amounted to $130m for fifty-seven projects over three years. Despite the fact that more

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money was going to fewer projects, the percentage of costs covered by the EC dropped from 50% to between 25% and 40% because the experiments in DRIVE II cost more than those in DRIVE I. Firms, and national and local governments supplied the remainder.

Poor relations between DG-XIII and DG-VII continued to hamper the new program. The DRIVE managers' attempts to promote implementation only made relations worse. Their outreach activities to national transportation administrations had annoyed some in DG-VII, who felt that the telematics researchers were invading their jurisdiction. At one DRIVE II meeting held in Brussels in the Spring of 1994 where EC representatives made presentation to national representatives, DG-VII representatives publicly disavowed recommendations made by DG-XIII. As all present could see, the Directorate responsible for transport and the Directorate responsible for telematics did not share a common vision of transport telematics.

ERTICO began its life coordinating the projects in DRIVE II. Although it performed many of the same functions of SECFO -- standard-setting, identifying cross-cutting issues, and working for implementation -- its approach was different. ERTICO hosted participatory committees, so that all relevant parties could take part in the consensus process. And it made possible high-level representation for issues involving members' interests. The consensus that ERTICO facilitated was both broader and more attuned to the interests of powerful players than that of SECFO.

The real content of DRIVE II was its field tests. In order to plan field tests for DRIVE II, two organizations had been created in the final year of DRIVE I. The CORRIDOR group was a

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forum for planning inter-urban (freeway) projects for DRIVE II. In CORRIDOR infrastructure
owners could exchange information and share experiences in the planning and conduct of field
tests. Its members were largely public administrations that had participated in the DRIG group.
The second organization for field tests was POLIS, a forum of city transportation agencies
throughout Europe. Like CORRIDOR, POLIS allowed for information-sharing and joint
planning of field tests.

In POLIS, some DRIVE planners noted that they were arguably too successful in attracting city
administrations: a number of mayors, including those of Athens, Lyon, and Barcelona, made
personal visits to the European Commission to lobby for funds for their cities. Their
enthusiasm was a mixed blessing. On the one hand, they were able to assemble funding to apply
to field tests. In particular, POLIS cities worked with the EC Directorate for Regional
Development to obtain structural funds to complement DRIVE funds for field tests. On the other
hand, a familiar pattern appeared as the number of field tests grew larger than anticipated,
requiring funds to be spread thinly. The addition of structural funds could not compensate for the
fragmentation of the program into many field tests.

Figure 6-9 shows a map of the test sites identified by CORRIDOR and POLIS. Given the
limited funding available for field tests, the large number of proposed sites meant that most of
them ultimately received little or no funding.
Figure 6-9: Pilot Project Proposals
Ultimately, DRIVE II funded some thirty pilot projects. A pilot project in London gave evidence of the small funding available for field tests. The APPLE field test of an in-vehicle route guidance system received only $1 million of DRIVE funding for its three-year lifetime. Yet program organizers compared APPLE to the ADVANCE field test in Chicago which received $40 million of U.S. funding for five years. The APPLE test would also include only 200 vehicles, whereas ADVANCE was to include some 5000 vehicles (later sharply reduced.) With so may field tests approved in DRIVE II's limited budget, each one faced severe constraints.

DRIVE II was not without its promising projects, however. The SOCRATES project explored technology similar to Siemens' ALI-SCOUT, except it used cellular telephone. Data about current traffic conditions was collected from vehicles, and area-wide traffic information was broadcast to all vehicles in an area. Other projects investigated the use of FM radio frequencies for supplying simple traffic messages to drivers. This system held out the prospect of near-term, affordable implementation. Both PROMETHEUS research and work growing out of the LISB field test also received funding from DRIVE II. Ultimately, however, DRIVE II contained a small project for nearly every constituency.

DRIVE II ran from 1992 through 1994. During that time it still could not overcome the problem of fragmentation. Graphic evidence of the resulting lack of coherence could be found in DG-XIII's 1993 annual report, which represented the overall program as a matrix of fifty-seven rows (the different projects) and twelve columns (the different project areas and types.) Overall coherence remained elusive. Figure 6-10 shows this matrix.
### Key:
- AREA ADDRESSED
- PRINCIPAL AREA

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Adapting to the Institutional Reality

Toward the end of DRIVE II the limits on the program were beginning to be recognized. For six years participants had been unable to define a comprehensive system and to fund large field tests. As a result, they began to modify their vision to align it with this reality. They began to adjust their expectations downward. In the conflict between the technical vision and the institutional reality, the institutions were winning.

National transport ministries showed little inclination to invest substantial funds in creating an integrated system of transport telematics. DG-VII refused to collaborate with DG-XIII. The German Ministry of Transport had not joined either ERTICO or the PROMETHEUS Council. After six years of DRIVE research, transport ministries were not willing to pick up the development work of DG-XIII and carry it further.

In 1993 Federico Filippi, the Managing Director of ERTICO, voiced a conclusion shared by many when he wrote, "Clearly a unique pan-European [Transport Telematics] architecture will never exist." Without a single strong entity to implement transport telematics in Europe, different small applications would go forward in diverse national, regional, and local organizational contexts. ERTICO would work to ensure compatibility among diverse systems, but it would not define a single European system. ERTICO's task was to harmonize the diverse systems developed at lower levels.

Thus the attempt to develop an integrated, pan-European system of transport telematics
ultimately gave way in the face institutional barriers. The original vision implied a pan-European social organization that neither existed nor could be created. DG-XIII succeeded in translating its vision into a research program and even in winning the support of some of the players needed to implement the program. Its greatest success, ERTICO, constituted a major step towards pan-European cooperation. However, the players that figured most prominently in the social organization, the national transportation ministries, refused to commit.

The new technical vision that began to emerge during and after DRIVE II more closely conformed to the existing institutional order. The most significant sectoral institution was the governance structure of transport in Europe, which defined the many national transport ministries that would independently implement transport telematics. They had little interest in a visionary system; instead, they were concerned with piecemeal applications to achieve measurable, near-term improvements in traffic and safety. The goal of planners with a pan-European vision adjusted downward to this reality. Their European vision became one of ensuring that different systems could connect with each other. From a concern with system architecture, ERTICO's focus shifted to interoperability.

In 1995 a third DRIVE program was authorized in DG-XIII. Furthermore, within DG-VII a major program in transport policy research was also undertaken. This examined the possibility of deploying ITS on the Trans-European Road Network. Meanwhile, ITS development had moved forward in PROMETHEUS.

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PROMETHEUS Execution: Problems Emerge

In parallel to the two successive DRIVE programs, PROMETHEUS began its activities. The unfolding of the PROMETHEUS Program manifested many of the same trends as DRIVE. Beginning as a fragmented research program, planners worked hard to integrate the many activities and to bring them to implementation. Unlike DRIVE, however, PROMETHEUS could at least partially implement its vision, for the same car companies funding research controlled decisions over implementation. Although the program ultimately reduced its technical vision to align it with institutional realities, it nonetheless succeeded in implementing some systems in vehicles.

As described earlier, following the launch of PROMETHEUS in June 1986 researchers spent fourteen months defining tasks and organization. During that time they had little success in convincing public ministries to join, while they barred electronics firms from the Steering Committee. Only after releasing the Topics of Research at the symposium in November 1987 were electronics firms allowed to join PROMETHEUS.

At this time DG-XIII planners were selecting the proposals to receive DRIVE funding. In Berlin Siemens was recruiting local residents to serve as test drivers in the LISB technical field test.

In the first six months of 1988 the main activity in PROMETHEUS was the fielding of inquiries and the evaluation of proposals for research projects. Electronics and supply firms submitted a total of 649 proposals for cooperation in the program. These proposals had to be compared

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against the overall research agenda and against each other and the best proposals selected for inclusion. In June 1988 the final selections were announced. Of the 649 proposals, 224 were accepted for inclusion in PROMETHEUS. These research projects would now join the on-going projects pursued by the automakers and the research institutes.

The nationality of the proposals revealed the degree to which PROMETHEUS was a German initiative. Although a pan-European program, firms in Germany were far more active than others. Of the 649 proposals, fully 524 came from just Germany and France. The distribution of awards of contracts revealed national influences even more clearly. Of the 224 projects accepted, more than half (114) were from Germany alone. France and the UK were next, with 41 and 26 projects respectively.

No sooner was PROMETHEUS underway, than problems began to emerge. The first problem was a shortage of funds. In 1989 the German Ministry of Research and Technology reduced its support. The ministry reduced its funding of research institutes from 100% coverage to 75% coverage and required automakers to make up the shortfall. Furthermore, it required that any PROMETHEUS projects that might fit in DRIVE should be shifted from the nationally-funded program to the EC program. When DRIVE opened for bids in October 1988, a large number of the proposal were PROMETHEUS projects that were being shifted to the EC.171

Top management in the automobile firms soon began seeking ways to cut costs as well. The booming European market for autos was entering a period of decline, and top management

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support for PROMETHEUS waned. In an internal reorganization in the Daimler-Benz research department, a top supporter of PROMETHEUS left the firm. Soon thereafter, Dr. Panik changed positions in Daimler-Benz, moving to the firm's subsidiary in Brazil and leaving Glatt:he to represent Daimler in PROMETHEUS. With less subsidy from the government, PROMETHEUS planners felt they had to reduce costs.

In addition to costs, coordination also quickly emerged as a problem. Even with the transfer of projects to DRIVE, PROMETHEUS remained large and complex. With all projects selected and research taking off, PROMETHEUS planners confronted their new creation and found that they could not maintain control. Hundreds of projects were underway, many of them only loosely-linked with each other. Since public funding came directly from national governments, PROMETHEUS often resembled a collection of national programs rather than a single coherent program. Even when one research stream was well-integrated, it often did not link with other streams. The PRO-GEN group examining the social requirements and impacts of the technology, generated thick reports on strategies of implementation that many of the technical groups never even read. Integrating the hundreds of research projects proved to be nearly impossible.172

Finally, external relations with the transport ministries remained stalled. The German Ministry of Transport had not joined the PROMETHEUS Council, leaving the many German industrial participants with no close connection to those with responsibility for traffic. Over time the PROMETHEUS planners did succeed in developing communication channels with an international association of ministries, the European Council of Ministers of Transport (ECMT).
But the close working relationship envisioned in the PROMETHEUS Council never developed.

**Adjustments to Technology and Organization**

In the spring of 1989, in a series of intensive planning sessions, the automakers in PROMETHEUS modified their program. The changes resulted from the need to demonstrate results from the research investments and to bring coherence to the program.

The first change in the program occurred in the definition of the technology. In early 1989 PROMETHEUS planners redefined the technical vision to more closely connect research to program goals and to provide near-term benefits.

PROMETHEUS technology was redefined in terms of twenty-three "PROMETHEUS functions" and ten "Common European Demonstrators." The PROMETHEUS Functions reconceptualized the program, moving the emphasis away from pure technology and toward the useful functions to be gained and the benefits to be achieved. Instead of focusing on actuators or communication protocols, the functions defined PROMETHEUS in terms of higher-level building blocks like vision enhancement (Function 5), Obstacle Detection (Function 1), and Commercial Fleet Management (Function 23).

The ten Common European Demonstrators (CEDs) also increased the emphasis on benefits. Each of the CEDs combined PROMETHEUS Functions to perform such high-level tasks as driver vision enhancement, collision avoidance, traveler information, fleet management, and area-wide

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traffic management. The CED’s were designed so they could be realized by the end of the program in 1994. PROMETHEUS was shifting to a near-term perspective, defining products that could be realized in its lifetime.

The shift in emphasis to implementation affected the technology design. To define realizable technology, the technical vision had to adapt to what was technically and institutionally feasible. Technical feasibility meant applying existing technologies and not developing everything from scratch. The Common European Demonstrators involved much less basic research than the earlier definition of the program. Institutional feasibility meant restricting the vision to coincide with participation in the program. Given the consistent inability to work with public agencies, the Demonstrators emphasized stand-alone on-vehicle devices. Systems that required vehicle-roadside interaction were not institutionally feasible, because public agencies had never joined the program. Only one Demonstrator contained traffic management functions; others were add-devices for the vehicle that could function without any roadside equipment. In the face of public sector intransigence, the PROMETHEUS vision adjusted.

In the changes of 1989, PROMETHEUS evolved from a comprehensive basic research program into a focused technology development program. The goal was now to demonstrate the technical feasibility of devices that could be quickly converted into products. These devices would require no changes in the laws or regulations for transportation, so their implementation would not become entangled in policy questions of, say, road pricing.
The original vision of revolutionary improvements in safety and systemic harmonization of traffic flows was dropped. PROMETHEUS stopped trying to redesign traffic and instead focused on the familiar add-on approach to vehicle electronics. The attempt to go from product development to social engineering had failed, and PROMETHEUS returned to product development.

The adjustments in PROMETHEUS's technology and organization took place in anticipation of a planned mid-term demonstration event in Turin, Italy. There, nine of the ten demonstrators were shown. Improvements to drivers' vision was achieved with the use of ultra-violet headlights. Intelligent cruise control allowed vehicles to not only cruise at a steady speed but also to detect slower vehicles ahead of them and change speed appropriately. Map databases on CD-ROM allowed onboard information systems to guide drivers to their destinations. These systems and others -- nearly all of them stand-alone and requiring little or no infrastructure -- were demonstrated in their early stages.

The remaining two-and-a-half years in PROMETHEUS were a race to develop the demonstrators to the point of being viable prototypes. The grand vision of a vehicle-roadway system was no longer pursued. PROMETHEUS developed devices for the vehicle alone.

The final event in PROMETHEUS was a conference and technology demonstration in Paris in October 1994. The technologies demonstrated in Turin were again shown, this time in a more refined state.
PROMETHEUS ended in November 1994. It had succeeded in developing new technologies apply to automobiles that would possibly lead to marketable products. However, the real innovation of PROMETHEUS, the system approach, had failed. The early slogan of the program, "It's good-bye to the add-on approach!" had proved premature.

What PROMETHEUS revealed was that the add-on approach reflected a deeper institutional reality. In the governance structure in road transport automakers exercised control over autos but not over infrastructure. Panik and the others launched a program in pursuit of a vision that extended beyond their authority. To the outsiders who figured in that vision, the researchers were unrealistic dreamers who, if ignored, would eventually go away. And indeed, ignored by the public agencies with responsibility for traffic, the researchers remained stymied and eventually modified their grand vision.

Ultimately the automakers adjusted their vision to the institutional reality. They abandoned their systemic vision and focused on what they could control, the automobile. Instead of redesigning traffic they added devices to their vehicles. Their autonomous systems mirrored the mutual autonomy of the automakers and the transportation administrations.

Although the system vision was not realized, PROMETHEUS succeeded more at implementation than did DRIVE. At least automakers could implement their technology in their own vehicles. Research and implementation took place within the same institutions, the automobile firms.
In contrast, DG-XIII had no implementation authority at all for transport. The Directorate was a pure research funding organization. Its vision of a traffic system had nowhere to go, and so DRIVE remained stuck in a continuing program of small-scale tests. The barriers DRIVE encountered were much more less permeable.

Both PROMETHEUS and DRIVE failed to achieve their ambitious visions. In its LISB field test Siemens fared considerably better. With a more advanced starting point and a less ambitious vision, Siemens nearly succeeded in realizing its system.
Execution of the LISB Field test

As recounted above, by 1985 Siemens' LISB field test was ready to begin. In 1984 and 1985 Siemens had assembled all the supporters needed to test its technical vision. The Senate of Berlin and the federal ministries for traffic and technology all supported LISB, although they had imposed conditions for that support. Siemens took Bosch as its partner, modified its technology to incorporate Bosch's in-vehicle unit, and created a Steering Committee headed by the two federal ministries. With these steps taken, the coalition of supporters matched the needs of the field test. LISB could focus on technology.

The execution of LISB ran through March 1991. The program was executed in three phases: planning, implementation, and operation/evaluation. In the first phase of planning, the system design process was intermingled with the coalition-building process. With arrival of Bosch the in-vehicle display was changed, but otherwise the technical design remained that proposed by Siemens. The greatest design activity went into the site-specific features for the Berlin street network. Of the approximately 1800 miles of streets, 400 miles of surface streets and 45 miles of urban freeway were defined as the primary network, to be modeled on the central computer and outfitted with beacons at strategic intersections. Figure 6-11 shows distribution of infrared beacons on the Berlin street network.
Once the technology design and site planning were completed, Phase II of LISB could begin. Running from 1986 through 1988, Phase II served to install the system. Vehicles, drivers, beacons, and computers had to be prepared. A fleet of nearly 700 vehicles, composed of privately-owned vehicles, taxis, rental cars, and company fleets, had to be equipped with the on-board systems. Drivers also had to be recruited. Announcements in local newspapers in June 1987 attracted thousands of inquiries, and ultimately some 400 Berlin residents were selected on the basis of their driving patterns, the model of their car, and their age and income. Additional drivers came from users of company-owned vehicles in the Berlin area. A total of 240 infrared beacons also had to be installed. Since Berlin's traffic signals were already connected by cable to a central computer, no additional cable was required to connect the beacons to the central computer. Finally, a central computer for computing vehicle routing was installed in the same room as the central traffic control computer. By early 1989 the Berlin installation was ready to begin operations.

Phase III consisted of operations and evaluation. From 1989 until spring of 1991 the field test was executed and its results evaluated. For the first week of operation, in March 1989, the system broadcast static traffic information that reflected average travel times from beacon to beacon. One month later, the system went into full operation. Live traffic data was collected by measuring the driving times of vehicles between beacons, the central computer modeled overall traffic patterns, and drivers received up-to-date recommendations. For nearly two years the system operated, with vehicles using the information and real time route guidance.
recommendations to select the sequence of streets to their destination. Throughout the test, drivers were regularly interviewed and polled concerning their use of the system, the benefits they derived from it, problems that they experienced, and their willingness to pay for services.

During these two years some technical problems did emerge. The original wiring in vehicles caused interference with car radios and had to be modified. In some vehicles with a metallized coating on the windshields, the infrared communications were partially blocked. This was corrected by increasing the power of the infrared beacon. Thus, although the field test revealed shortcomings, they could be resolved.

In the spring of 1991 LISB officially ended. Elsewhere in Europe, PROMETHEUS was preparing for its first technology demonstration in Turin, and DRIVE I had just entered its final year.

LISB proved the feasibility of the ALI-SCOUT technology. The vehicle-roadside communication link was feasible on a large scale. Drivers found the information supplied by the system to be credible and most of them followed the recommended routes. The traffic data collected from vehicles proved to be of high quality and much lower cost than data collected by sensors buried in roadway. The improved data collection also allowed for improved traffic management through control of regular traffic signals. Thus, by the end of the field test, in March 1991, LISB had given strong indications that the technology offered benefits for both consumers and city traffic departments.

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Changes in the Context of LISB

If the ALI-SCOUT technology in LISB had worked largely as predicted, other factors proved less predictable. The political and social context around LISB changed dramatically during the two years of the field test. Changes occurred that powerfully affected not only Berlin but all of Germany.

First, the Berlin Wall came down, and Germany was reunited shortly thereafter. Berlin ceased to be an island separated from its surroundings by a wall. The immediate effect of this on LISB was to alter traffic patterns in the city. What was previously a closed street network with regular traffic patterns now became both larger and less regular. However, Siemens could adapt the system design to this change. Some additional outlying beacons ensured adequate communications coverage for the new network.

More importantly, German reunification radically changed the financial condition of the national transport ministry. For the foreseeable future, investment in transportation infrastructure would go to road construction in the East, where roads were far below Western standards. That meant that any implementation of ALI-SCOUT systems in Germany would not be financed by the public sector. Even if the technology worked and provided benefits, public funds for implementation were no longer available. Although Siemens had not yet made explicit plans for selling ALI-SCOUT to public authorities, public procurement would have been the most obvious because it repeated the approach for traffic control systems.
The second change that occurred during the field test was in the Berlin Senate. In local elections in 1989, the conservative Christian Democratic Union (CDU) majority was replaced by a left-leaning "red-green" coalition of the Social Democratic and Green Parties. With the political change, the attitude of the city government towards the LISB field test changed dramatically. Where the previous government concerned itself with improving traffic, the new government had been elected with an environmentalist agenda. Green Party members of the Senate regarded LISB with deep skepticism. ALI-SCOUT would increase the efficiency of road network usage, thereby reducing congestion; however, by reducing congestion, it would make private automobiles a more attractive mode of travel in the city. The Green Party was strongly opposed to any measures that promoted automobile usage. Siemens' Berlin partners were now the system's greatest critics.

This political shift toward environmentalism was not limited to Berlin. Similar developments occurred in other cities in Germany. In a series of German city elections in the early 1990s the Green Party entered into governing coalitions in Munich, Frankfurt, and Hannover.

The new politics posed a major threat to Siemens. Not only was the LISB field test jeopardized, but other test sites being prepared were now at risk of being canceled. In Munich, where Siemens had received funding from DRIVE II for a small test, the new Green city government cast doubt on the future of that system. The Munich officials now wanted to facilitate public transport, not private vehicle use.\(^{176}\)
Siemens survived these changes by redesigning the system. The changes in city governments were accommodated through changes in the design of the technology. In the years from 1990 through 1992, even as LISB was underway, Siemens designed a follow-on system to ALI-SCOUT, called EURO-SCOUT. Many of the design changes that it incorporated reflected the environmental concerns of city governments.  

First, EURO-SCOUT would no longer be purely automobile-oriented, but would promote the use of public transport. Changes to the information supplied by the system made this possible. Instead of supplying only vehicle route guidance information, EURO-SCOUT would also supply mass transit information so that drivers could change modes. When a driver input a destination, the system could give guidance to the nearest park and ride facility where the driver could leave the vehicle and take mass transit. EURO-SCOUT would supply information about the availability of parking and about the schedule of the next appropriate train.

Another change in EURO-SCOUT was to make the display unit portable. Once it had stored a series of instructions in its memory, the unit could be carried in the driver's pocket to provide guidance on a series of trains or buses. Even after the switch from the private vehicle to mass transit, EURO-SCOUT would continue assisting the traveler. Figure 6-12 illustrates how the system would guide drivers to Park and Ride (P+R) facilities, where they could switch to transit and receive continued route guidance from the portable unit.

Finally, with an overall system design based on a single central computer, EURO-SCOUT could

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promote a variety of policy goals through changes at the center. The route guidance recommendations emanating from EURO-SCOUT's central computer could include environmental considerations. Should a city government desire to discourage vehicle use inside its cities, it could program EURO-SCOUT's central computer to simply not accept destinations in a city center. Or, should smog become a problem during certain days, the allowable range of destinations could be restricted or expanded accordingly.\textsuperscript{179}

Fortunately for Siemens, much of the new "green" functionality could be realized using the original design. The only changes made to the hardware of EURO-SCOUT was that the transmission capacity of the system had to be increased eight-fold to accommodate transmission of transit schedules, and the in-vehicle unit rendered capable of autonomous functionality. For the rest, changes in the central computer's software allowed for the realization of new functions. Mass transit schedules had to be added to the database, together with the ability to compute recommended routes involving a modal switch at a park-and-ride facility.
Figure 6-12: EURO-SCOUT Notifies Driver of Park & Ride Facility, Provides Route Guidance on Transit, Can Be Used As Hand-Held Unit

Transit Line

Freeway Exit

NO PARKPL. AT WATERFRONT -> P+R

km

8.2

Transit stops related to DRG destinations areas

Hand held use of the EURO-SCOUT terminal
Not only could Siemens' design accommodate environmental demands, it could also accommodate an implementation approach based completely on private investment. EURO-SCOUT had two features that made it well-suited for market implementation. First, the system was able to incorporate an electronic card with which to charge users for receiving information. In order to enable data reception, drivers would need to insert a pre-paid debit card into their in-vehicle unit. This mechanism allowed Siemens to charge individual users for the broadcast data. The use of smart cards had already been foreseen in the planning of LISB, but the loss of public funding for advanced infrastructure rendered the smart card more salient. The smart card made it possible to finance the system from user fees. If consumers were willing to pay enough for the services, private firms could implement the entire infrastructure as a profitable investment.

The second aspect of EURO-SCOUT that made it well-suited for private implementation was its low reliance on public infrastructure. Traditional traffic control systems, including Bosch's original ALI system, sensed traffic with inductive loops buried in the roadway. Since the loops were installed and maintained by public authorities, no such system could be implemented without intensive public participation. Siemens' "floating car" method of collecting traffic data from vehicles avoided this interdependency. Private vehicles could supply the data, avoiding the need for new sensors and, hence, for public sector participation. Granted, EURO-SCOUT still relied on beacons mounted on public lightposts and on a central computer, but the public-private interdependencies were quite low.
Thus, even though it functioned largely as anticipated, Siemens' ALI-SCOUT technology was substantially redesigned in the EURO-SCOUT version. The reunification of Germany and the election of Green Party coalitions in German cities had required changes to the system design.

**Stage 4 (Deployment): The CO-PILOT Consortium**

Following the LISB field tests and the design adaptations in the EURO-SCOUT technology, Siemens focused its attentions on deployment. In the field tests Siemens had explored issues of technical feasibility and user willingness to pay; now it would have to investigate the financial, organizational, and political issues surrounding implementation.

By 1992 planners at Siemens had drawn two conclusions. First, EURO-SCOUT would not be implemented by the public sector. The reunification of Germany had drained the public purse.

Second, EURO-SCOUT could not be implemented by Siemens alone. This was not solely because of the high cost of the system. True, installing the needed 20,000 beacons throughout Germany would cost $328 million, according to Siemens -- and double that, according to BMW. Whether any one firm would invest so much capital remained doubtful. More significantly, other German firms with competing systems would likely object to the government's endorsing Siemens' technology. Implementation of infrastructure, even if privately financed, was a public affair and would require political consensus among relevant actors.
The solution to this dilemma was to create a corporation that was neither public nor fully private. German firms would join together in a common operating company in which they would all invest and would all derive earnings. The company would invest private capital, thus solving the problem of the public sector's lack of funds. And it would be a cooperative venture, thereby solving the problem of consensus among the firms.

Of course, such a company would have to obtain a license from public authorities in order to install the system. Moreover, local authorities would want to retain control over policy decisions to discourage automobile use or encourage a switch to mass transit. To achieve this, the central control room would be under the jurisdiction of public authorities. Their authority would be protected -- indeed, it would be enhanced by the new abilities in the technology. In return, the private firms would be allowed to install the system and collect fees from users.

Throughout 1992 and 1993 Siemens negotiated with the other leading players in transport telematics to create a operating company. The most active partners in negotiation were Daimler-Benz, Siemens, and Bosch. Their talks focused on funding, organization, governance, and legal implications of a common venture.

In mid-1994 the CO-PILOT corporation was created to plan, install, and operate Euro-Scout in Germany. The main investors were Siemens, Bosch, and the Daimler-Benz subsidiary Intertraffic. Each invested approximately one-third of the initial capital, thereby guaranteeing that no one firm exercised control. The firm would oversee a group of regional operating
companies to finance, install, and operate route guidance systems.

Since each of the partners had invested in different technologies, a potential conflict existed about whose system to use. This was resolved by accepting all technologies. CO-PILOT would make its money from selling information services. These services, however, could be distributed over any number of different systems. Initially, CO-PILOT would install EURO-SCOUT technology, since this was the most ready for market. However, systems supplied by other firms and using alternative technologies like cellular telephone rather than infrared beacons could still distribute the same information. The market for services was greater than the market for hardware.

Thus, by the end of 1994, Siemens had moved its vision through a field test and towards the market. While other European initiatives focused on a grand vision to be realized through research and development, Siemens took a more incremental approach. Beginning from a leading position as a traffic signal supplier, Siemens designed a system for driver information that took advantage of existing infrastructure. The LISB field test then tested the technical feasibility under real world conditions and provided initial market data. Siemens redesigned the technology to allow additional communications for environmentally-oriented information. The CO-PILOT corporation served as an institutional mechanism for implementing the system. Neither public nor fully private, this common operating company allowed the leading private investors in ITS to undertake implementation and operation. By 1994 CO-PILOT was underway.¹⁸¹

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Summary

By the end of 1994 all three European programs had passed important milestones. Each program began with a similar technical vision of a transportation system linking vehicles and roads. Conceived, launched, and executed in different contexts, however, each yielded quite different results.

Siemens conceived and launched the ALI-SCOUT system largely on its own. Already in the markets for both vehicle electronics and traffic management systems, Siemens was well-positioned to develop a vehicle-roadside system. Furthermore, its technology had already undergone considerable development in small-scale tests. Thus the LISB field test was an incremental advance from both Siemens' current market position and its current technology. Then Siemens created its own opportunity to launch LISB. The coalition that it assembled reflected the needs of the system rather than the requirements of any institutional framework promoting such a field test. In the following execution, it successfully navigated through the surprises and setbacks it encountered. Confronted with unforeseen demands for environmental functionality, von Tomkewitsch redesigned the system to promote mass transit usage. Surprised by the reunification of Germany and the resulting disappearance of prospective public funding, Siemens created CO-PILOT to fund, install, and operate the system.

PROMETHEUS was less successful. Its use of top-down planning to create a comprehensive traffic system bore little relationship to automakers' authority. Automakers made autos, but had little experience with the roadside infrastructure that figured so prominently in their

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vision. In creating a technical vision, the automakers implicitly made decisions for the public administrations managing roads. This strategy of making plans about other groups was risky. Despite this mismatch between the composition of the planners and the scope of the plan, the EUREKA framework allowed PROMETHEUS to get launched. Participation, however, did not expand. Public authorities refused to join an industry program. Especially damaging was the continued refusal by the German Ministry of Transport to join. The PROMETHEUS Council was one mechanism intended to bridge the gap, but it failed. Unable to overcome institutional barriers, the automakers used technology design to salvage the program. They revised their ambitious vision, replacing the system with Common European Demonstrators (CED). The CEDs were a far cry from the original system vision, however. Panik's bold slogan "It's good-bye to the add-on approach" proved premature, since most CEDs were in fact add-on devices. They conformed to existing institutional boundaries, requiring no collaboration between automakers and public authorities to be implemented. Redesigning the technology to conform to existing institutional boundaries, automakers achieved implementation at the expense of their vision.

Finally, the DRIVE program had the least success of the three programs. Whereas the automakers in PROMETHEUS could implement technology in the vehicle as their last resort, DG-XIII exercised no authority for implementation in any domain. DG-XIII's efforts remained stymied at the research stage. It saw transport telematics as a promising application of its telematics technology, but transportation authorities saw little convincing evidence of benefits. As in PROMETHEUS, the researchers in DRIVE had developed a vision on behalf
of transportation authorities, and those authorities had refused to fund field tests and implementation. Huber devised a number of strategies for overcoming institutional resistance, most notably the Strategic Consultative Committee that then led to ERTICO. Ultimately, however, the director of ERTICO and the leadership of DG-XIII acknowledged that a single European system could not be designed for a myriad of national transportation ministries. The vision was changed to one of interoperability of multiple different systems, a technical design that better corresponded to the institutions of European transport.

The three different outcomes of these three different projects can be best explained by the sectoral institutions within which they unfolded. In all cases the system vision crossed boundaries of many existing organizations. In all cases, development moved forward where boundaries were least pronounced, and remained blocked where boundaries were great. Organizational boundaries determined the extent of development. As an organization, Siemens linked the vehicle and the roadside, and it already had working relationships with city governments like the Berlin Senate. As a result, it brought development the farthest. The automakers in PROMETHEUS had few links to operators of roadside infrastructure and so could not carry implementation farther than the vehicle. DG-XIII had no authority for implementation, but did have many relationships with firms involved in ESPRIT and RACE. As a result, it could not implement on the roads; ERTICO remained largely an industry association. In all three programs, the final system design largely reproduced the social order within which it developed.
Chapter 7

ITS DEVELOPMENT IN THE UNITED STATES

The U.S. had been a leader in ITS until 1971 when ERGS was cancelled. It was not until 1991 that the U.S. would again have a national program in ITS. Having been the first to start ITS research, the U.S. experienced a twenty years hiatus. However, despite its late start the U.S. program quickly surpassed others in the scale and breadth of activity of its government-funded program.

This chapter recounts the process by which the ITS program was proposed and launched, as well as the activities of the first three years of development. With less time passed in the U.S. program than other programs overseas, however, this account cannot attempt an evaluation of the final outcomes of the U.S. activity. Unlike programs in Germany or Japan the U.S. has achieved only modest deployment of vehicle-roadside systems. Yet considerable activity has taken place that reveals the influence of sectoral institutions.
Sectors, Actors, and Sectoral Institutions

Before considering the history of ITS development in the 1980s, we consider the sectoral context within which development took place. This section analyzes the relevant sectors, the organizational actors within those sectors, and the sectoral institutions that structured resources needed for ITS development.

The previous case histories of Europe and Japan analyzed four sectors: vehicles, road transport, communications, and technology. In the U.S. the set of relevant sectors was slightly different. Like overseas programs, the ITS vision mapped onto the automotive, road transport, and communications sectors. However, the U.S. possessed no technology-oriented frameworks for funding comparable to MITI in Japan and the Ministry of Research and Technology (MRT) in Germany. Instead, a fourth sector that figured prominently in the U.S. program was the defense sector. Firms in the defense sector sold advanced technology to publicly-funded programs; as such they were able to win a role for themselves in the ITS program.

The automotive sector consisted of the “Big Three” automakers, General Motors (GM), Ford, and Chrysler. These firms had both in-house electronics capabilities (e.g. Delco Electronics within GM) and associated defense technology companies (such as Ford Aerospace and GM’s recently-acquired Hughes Aircraft). However, these capabilities were more in the area of engine/ignition control (in the case of Delco) and advanced satellite technology (in the case of Hughes). No automakers were active in traffic-related electronics.

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The road transport sector at the national level consisted of various federal agencies within the U.S. Department of Transportation (USDOT). Foremost among these was the Federal Highway Administration (FHWA), which had been active in the planning and funding of road construction since the early days of the automobile. Since 1956 the FHWA had overseen the planning and construction of the Interstate Highway System, a network of some 43,000 miles of high-speed roadways just being finished in the 1990s. Two other relevant agencies in USDOT were the National Highway Safety and Traffic Administration (NHTSA), with regulatory activities for safety, and the Federal Transit Authority (FTA, called before 1991 the Urban Mass Transit Administration) concerned with transit.

State and local DOTs were equally important actors in the road transport sector. Since the sector was organized according to federal principles, state and local departments of transportation (DOTs) exercised considerable autonomy. Federal and state agencies collaborated more as partners than as superiors and subordinates in the planning of the Interstate.

Within the road transport sector two national associations represented the interest of road users and state officials. The American Association of State Highway and Transportation Officials (AASHTO) represented state DOTs. The Highway Users Foundation for Safety and Mobility (HUFSAM) represented user industry interests such as automobiles, petroleum, and rubber. Both associations exercised a strong voice in policy in the sector.

The third sector, communications, consisted of a diverse set of firms. Foremost among these was

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Motorola, which was a world leader in mobile telephony products. Other relevant firms were AT&T and the regional Bell operating companies. However, the U.S. had no firms like Siemens or Sumitomo Electric that were large communications firms with an established presence in the transport sector. This absence reflected the fact that the U.S. had not implemented computerized traffic control systems in the 1970s and 1980s, as had the Germans and the Japanese, and so had not created a traffic electronics industry. Thus the U.S. possessed strength in such component technologies as sensors, communications, and data processing, but few firms had developed traffic systems.

Finally, the defense sector did not figure in the ITS technical vision, but it ultimately played a significant role in the program. To the extent that the U.S. has had a technology policy, it has often consisted of publicly funded development projects performed by Rockwell, Hughes, Lockheed, and other electronics and aerospace firms. Within the Department of Energy national laboratories like Los Alamos also possessed advanced scientific and technical expertise. With the end of the Cold War this sector was shrinking, and defense firms and national laboratories were actively seeking new projects where they could apply their advanced technology. Table 7-1 shows the main actors for each sector.
Table 7-1: Sectors and Actors in the U.S.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Organization(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>General Motors, Ford, Chrysler</td>
<td>Private firms</td>
</tr>
<tr>
<td>Communication</td>
<td>Motorola, Delco, AT&amp;T</td>
<td>Private firms</td>
</tr>
<tr>
<td>Roads</td>
<td>FHWA, NHTSA, FTA, State DOTs, Local DOTs</td>
<td>Highway planning, Safety regulation, Transit, Construction &amp; operations, Construction &amp; operations</td>
</tr>
<tr>
<td>Defense</td>
<td>National Labs, Hughes, Lockheed</td>
<td>Advanced Technology, System engineering</td>
</tr>
</tbody>
</table>

The resources needed to realize the ITS technical vision could be found within and among these sectors. As in all ITS programs, these resources included expertise in component technologies, authority in the jurisdictions affected by development, and funding for the series of developmental stages.

These resources were organized by sectoral institutions. Sectoral institutions defined the sets of actors with control over resources. In order to realize the ITS vision, ITS entrepreneurs had to assemble the needed resources by building coalitions of the actors possessing or controlling the relevant resources.

The first sectoral institution, the division of labor, divided expertise widely. As just presented, all

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the needed expertise existed, but within different firms in different sectors. In this the U.S. was no different than other countries, except one. Only the German firm Siemens possessed broad expertise in vehicles, roads, and communications. Thus in the U.S., as in Japan and in most of Europe, assembling available expertise for a vehicle-roadside-communications system would require collaboration between automakers, electronics companies, and public agencies.

On the industry side, the division of labor left the U.S. expertise weak in two areas. First, with practically no consumer electronics industry, the U.S. was weak in in-vehicle electronics.\(^{182}\) Japanese consumer electronics firms like Sony and Pioneer and European firms like Philips and Bosch/Blaupunkt had all participated actively in overseas programs, developing and marketing in-vehicle CD-ROM readers with navigational capabilities. The development of in-vehicle units would require new capabilities from U.S. firms.

Second, and more significantly, the U.S. lacked widespread expertise in traffic control electronics. Countries like Japan and Germany had already installed traffic control systems nation-wide, and in doing this they had cultivated transportation-electronics firms like Siemens and Sumitomo Electric. With a modest history of computerized traffic control, the U.S. had cultivated no large traffic control electronics firms. U.S. firms like Motorola or Hughes did possess considerable expertise, but they would have to adapt that expertise to the needs of ITS.

Within the FHWA, the division of labor included expertise both in research and in operational program activity. As recounted in Chapter 4, the research branch of the FHWA had launched

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ERGS earlier and continued to house skills in traffic electronics. These skills had had little opportunity for application in the 1980s, however, as the Reagan administration gave transportation technology research a low priority. The program branch of the FHWA, on the other hand, was the site of most operational activity. Its skills lay more in planning and national coordination of Interstate Highway construction.

If the division of labor gave the U.S. no particular advantage, the same could not be said of the second sectoral institution, governance. The jurisdiction of the FHWA neatly matched what was needed for a national system of ITS. A single federal agency possessed authority to oversee the entire system, just as it had overseen development of the entire Interstate system. This stood in sharp contrast to Japan, where the Ministry of Construction and the National Police Agency uneasily shared authority, and to Europe, where a multitude of national ministries exercised authority. Unified authority in the U.S. matched the technical vision of a unified national system. The same agency, the FHWA, that had planned the Interstate would now plan ITS development.

Where the governance of U.S. road transport was less congruent with a national ITS vision, however, was in the limited authority the FHWA had over state and local DOTs. Although the FHWA had had a strong voice in Interstate planning, by no means did it exercise control over other levels. States owned and operated the Interstates within their jurisdictions. The FHWA's main control mechanism was the definition of categories limiting the kinds of projects to which federal funds could be applied. However, the agency could not control the actions of lower levels of government.

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The third sectoral institution was frameworks for funding. In the transport sector the main
framework for funding was the "Highway Bill," the legislation used to fund highway construction.
The Highway Bill was big, usually containing funding on the order of magnitude of $100 billion.
Every four to six years Congress passed this legislation to pay for the continuing construction of
the Interstate (and other programs.) Most revenue for highway spending came from the Highway
Trust Fund, which was supplied by gasoline and other user taxes and whose use was limited to
transportation-related spending.

The Highway Bill was under the control of a broad collection of actors. Unlike in Japan, where
national ministries largely set their own budgetary priorities, funding for road transport in the U.S.
was overseen by many actors in the "highway community." This highway community included
members of Congress, federal agencies, and various interest groups. Each member of Congress
represented a state receiving federal funds, and so each had a direct interest in the Highway Bill.
Those members occupying strategic chairmanship positions in legislative committees exercised
particular influence.

Among federal agencies, the FHWA exercised the most influence on highway priorities. Within
USDOT NHTSA and FTA also influenced funding allocations. AASHTO and HUFSAM, the
traditional interest groups for highway funding also played a major role. Within AASHTO rural
state DOTs outnumbered urban states, giving them a powerful role in road transport. The large
number of interests participating in funding decisions reflected the openness of U.S. political
institutions, while the particulars of those groups and the funding mechanisms they controlled

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reflected the institutions of the road transport sector.

The road transport sector was at an historical watershed in the late 1980s. Construction of the Interstate Highway System was nearly complete. Although highway maintenance would continue to be an important task, it offered little role for planners and technologists in the FHWA. In theory the many public agencies and industries in transportation might simply disappear, with their resources and expertise redistributed for application elsewhere. However, the reality was that after thirty years of Interstate construction the road transport sector had become institutionalized; the relevant actors had acquired both an interest in their own self-preservation and controlled the resources to ensure their own survival. The FHWA and the associated sectoral division of labor, framework for funding, and governance structures would endure in some form past completion of the Interstate.

State DOTs also felt pressure. With fewer and fewer states receiving large-scale funding, the overall distributive equity of highway funding across states began to decline in the late 1980s. States resisted this trend through the use of legislative earmarks, by which their Congressional representatives mandated funding for specific highway projects in their home states. Such earmarks constituted classic "pork barrel" spending; yet they also manifested the federal nature of U.S. political institutions that ensured that all states in the union could influence national programs.

The pressures created by completion of Interstate construction manifested themselves in the 1987
Highway Bill. That legislation was so loaded with earmarks for demonstration projects that it drew the first presidential veto in the history of the federal highway program. Congress overrode President Reagan's veto, and one hundred and fifty earmarks received funding.\textsuperscript{183} Nonetheless, it was clear that such actions would not endure for a long time. Road transport interests needed a new rationale for continued large-scale transportation outlays at the federal level.

This was both a problem and an opportunity within the road transport sector. The Highway Bill risked becoming a framework for funding without no project to fund, and the FHWA risked becoming an organization without a mission. Seen differently, the funding available in the Highway Bill and the Highway Trust Fund would become available for application to new activities after 1990 as a follow-on to the Interstate. An opportunity existed for a new initiative in road transport.

Thus by the late 1980s the forces at work in the federal road transport sector were clear: Congress and the states were hungry for continued federal transportation funds, and the FHWA needed a new mission. The Highway Bill scheduled for passage in 1990 presented the next decision point in road policy.

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Mobility 2000

Twenty years earlier the proponents of ERGS had foreseen the end of the Interstate as the opportunity which would allow them to launch a national program in ITS. Unfortunately for those early innovators, they misjudged the timing of the opportunity and their proposal for a national ITS program failed to receive Congressional support.

After the cancellation of ERGS in 1971 the ITS concept received little further attention in the U.S. Through the 1970s only modest activity continued. The greatest achievement in this period was Highway Advisory Radio, which broadcast up-to-date traffic messages to motorists via their AM radios. Then in the 1980s the Reagan administration terminated what little activity remained. Not until the end of two four-year presidential terms would ITS-related activities begin again.

Federal inactivity left the initiative with the state and localDOTs, a few of whom began implementing new technologies. In Los Angeles the city DOT computerized traffic signals for the 1984 Olympics. Outside of Washington, D.C., Maryland's Montgomery County also installed a county-wide traffic control system with a traffic management center. In sites throughout the U.S. freeway ramp metering systems were installed to control access to freeways and thereby maximize their capacity. Some states, including Texas, experimented with electronic toll payment technology which eliminated the need to stop at toll plazas. Thus early applications were appearing in a few DOTs, with most of them emphasizing the application of relatively simple technology to new operational settings. Although traffic control and ramp metering were far less
innovative than a full ITS vehicle-roadside communication system, they constituted a significant innovation for those organizations that implemented them.

Industry was active as well. Truckers and taxis were introducing computerized dispatching and fleet monitoring technologies to more efficiently manage their operations. A small company named ETAK introduced an in-vehicle navigation system allowing motorists to trace their position on a computerized map and select the best route to their destination. Although achieving little commercial success in the U.S., Bosch licensed the technology for further development in Germany.

Some ITS research was also underway, nearly all of it in California. Public agencies like the Los Angeles City DOT and the California state DOT, Caltrans, were testing new systems such as in-vehicle driver information systems with navigation guidance. Research in automatic vehicle control was also being conducted by the University of California in its PATH program (Program for Advanced Technology for the Highway)\textsuperscript{186}. A consortium of western states led by Arizona joined in the HELP/Crescent Program to develop systems for commercial trucking regulation through weigh-in-motion and electronic checking of shipping permits.

Despite these instances of innovation, however, the general experience of local DOTs with computerized traffic control was negative. Few local DOTs had invested in computerized traffic management systems, and those that did experienced difficulty operating and maintaining them. Traffic control systems required expertise in electronics and computer technology, resources not
readily available in DOTs. A 1990 report by the FHWA that surveyed twenty four representative traffic management systems found that only two "very well operated and well maintained traffic control systems." Even simple ITS-related technologies had not been widely implemented in the U.S. Unlike Japan, which deployed traffic control systems nation-wide in the 1970s and 1980s, the U.S. did little with this technology for two decades.

Thus a lack of interest and ability in ITS-related technologies characterized the entire road transport sector, from the FHWA to state DOTs to local agencies. Many individual instances of activity could be found, but these were drops of innovation in a sea of inactivity. In this context ITS advocates became active.

By the late 1980s ERGS was largely forgotten and many of its original proponents had retired. However, a few ITS proponents still occupied positions of authority, most notably Lyle Saxton in the research branch of the FHWA. In the late 1980s Saxton in the FHWA joined other researchers to organize support for a national ITS program.

Two groups of researchers, one at the University of California and another in the FHWA, came together to advocate ITS. The first relevant event was a meeting convened by the California state DOT, Caltrans, in October 1986. There, researchers from academia, government, and business first discussed the idea of a national program to develop vehicle-highway technologies to increase capacity without road construction. The University of California was already conducting a research program in related technologies, and participants agreed on the need to begin activity at

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the national level. Then in November 1987, at an unofficial workshop at the FHWA's Turner-Fairbank research facility, planning for the realization of such a program was begun. This led to a third meeting, a workshop in Berkeley, California, in March 1988 where thirty-nine participants, most of them researchers from FHWA, state DOTs, universities, and industry, met and began formulating a vision of ITS.188

These were the first in a series of tri-monthly meetings from 1988 until 1990. In these meetings supporters of a national program promoted interest in new technology for transportation and attracted new supporters. Participants adopted the name "Mobility 2000" for their expanding coalition of players supporting a national ITS program. Mobility 2000 elaborated a vision of ITS and assembled a coalition in support of a national program.

The lead advocate of ITS in the FHWA was Lyle Saxton. Researchers from the University of California were joined by colleagues from the University of Michigan, Texas A&M University, and the Massachusetts Institute of Technology (MIT). Active leadership also came from industry, especially from representatives from General Motors and Motorola. Over time representatives came from additional transportation agencies at the state and federal level. In addition to FHWA employees, attendees came from the National Highway Traffic Safety Administration (NHTSA) and state-level DOTs. Numerous transportation consultants also attended. When Mobility 2000 held its final national conference in Dallas in 1990, the names of over one hundred individuals appeared as contributors to their plan for a national program189.
Before 1989 the Reagan political appointees running the FHWA opposed the early activities by researchers to organize what became Mobility 2000. Lyle Saxton's early organizing activities with Mobility 2000 in 1987 and 1988 received no official support. With the election of George Bush as President in 1989, however, the policy of the administration and of USDOT toward technology became more favorable to research and development. The FHWA quickly became supportive of ITS.190

Although no formal declarations had been made, from 1988 to 1990 there had been numerous signs of FHWA's increasing interest in ITS. The newly appointed Administrator of the FHWA, Thomas Larson, openly supported ITS, commissioning a Discussion Paper and including it in the FHWA's long-term policy plan of October 1989. During 1988 and into 1989, personnel from FHWA and other USDOT agencies also began attending Mobility 2000 meetings. Growth in interest coincided with the change in administrations: attendance at a meeting in early 1989 in San Antonio Texas was triple that of a meeting held in California only eight months before191. Of the 57 attendees in San Antonio, many were from USDOT, indicating the new open interest in ITS. By 1989 other USDOT agencies, such as the National Highway Traffic Safety Administration (NHTSA), were also attending Mobility 2000 meetings and expressing an interest in ITS192.

As the FHWA became increasingly interested in ITS, it spread that interest to the new administration. The link between FHWA and the administration was the Office of the Secretary of Transportation. In 1989 the Office of the Secretary of Transportation conducted a study to
evaluate ITS, concluding in March 1990 that such a public-private cooperative program should be begun immediately\textsuperscript{193}. Almost simultaneously, President Bush’s Secretary of Transportation, Samuel Skinner, issued a national transportation policy report that mapped out a long-term U.S. transportation policy\textsuperscript{194}. The report stated that the U.S. needed to promote advanced transportation technology and should invest in technology development. The administration's commitment to ITS was made even more explicit when President Bush expressed his support for ITS in a speech of March 8, 1990. Thus by early 1990 the FHWA, USDOT, and the Bush administration were publicly committed to a national policy to develop ITS. No policy existed as of yet, but the executive branch of the federal government was supporting ITS.

The validity of the ITS concept was strengthened by reports from overseas. In the late 1980s Siemens’ LISB technical field test in Berlin was well underway. PROMETHEUS and DRIVE had also been recently launched. In Japan RACS and AMTICS had succeeded CACS. All these programs gave evidence of the validity of ITS and were cited by ITS proponents in the U.S.

Mobility 2000’s final national conference was held in Dallas in March of 1990. By that time knowledge of the proposal was widely diffused in the transportation community, and many participants considered its adoption likely. In the executive branch, the FHWA, the USDOT, and the President had all voiced support for the program. State-level DOT’s in AASHTO had also passed a resolution in support. A few key industry players like Motorola and General Motors had made public declarations of support. Needless to say, the research and academic community that had proposed ITS originally strongly backed the idea of an ITS program, seeing opportunities for

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research and a major rethinking of transportation education.

The product of Mobility 2000's activities were a vision of partnership, of funding, and of technology. First, the ITS program would be based on a public-private partnership in which private firms and public agencies would collaborate in system development. Public roads and private vehicles would be linked in a total system. The details of this partnership, however, were not worked out. Second, the level of public funding for the new program would be on the order of $100 million per year.\textsuperscript{195} This would be enough to support the broad program of research and development. Third, Mobility 2000 developed an ITS technical vision. This is described in the next section.
The ITS Technical Vision

Mobility 2000's main activity had been to create a broadly shared technical vision of ITS that would serve as the goal for a national program of technology development. Although a national program would consist of more than technology (e.g. organization and funding were needed as well,) Mobility 2000 placed its main emphasis on the creation of the technical vision.

The original term coined by Mobility 2000 members and used in the early years of the program was "intelligent vehicle-highway systems" or "IVHS." As the program unfolded and the applicability of the technology to all modes of transport became apparent, the term "vehicle-highway" was replaced with the more general term "transportation."

As presented in 1990 the overall technical vision consisted of four systems: driver information, vehicle automation, traffic management, and commercial operations. These systems roughly corresponded to four groups: the research branch of the FHWA, the transportation program at the University of California, the program branch of the FHWA, and industry. The process by which the overall vision came into being shows the relationship between technical vision, organized groups, and sectoral institutions.

The situation of U.S. researchers in 1986 resembled that of the proponents of PROMETHEUS in Europe: Mobility 2000 researchers approached a funding opportunity with a clean slate in hand, upon which they could envision their technology. Two of the four systems in the technical vision represented researchers' ideal vision of intelligent transportation.

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The first of these was Advanced Driver Information Systems (ADIS). This consisted of the basic ITS technical vision of a vehicle-roadside-communication system. ADIS was the same technical vision as had been proposed in ERGS and as was then under development in Japan (then completing RACS and AMTICS) and Germany (then completing the LISB field test). With the lead organizer of Mobility 2000 the same person who had led ERGS development earlier, the continuity from ERGS to the ITS program was evident.

The second system in the Mobility 2000 vision was Advanced Vehicle Control Systems (AVCS) for hands-off, automated driving. This area was the main interest of the transportation program at the University of California. With the national program to be an FHWA program, the California researchers emphasized those aspects of their work relevant to traffic congestion and highways. AVCS would develop electronically-linked trains of vehicles that would drive on urban freeways in close proximity and at high speed. Narrower lanes and higher speeds would raise the capacity of freeways, reducing urban congestion.

The third system was for traffic management. Advanced Traffic Management Systems (ATMS) would gather traffic data from sensors, model overall traffic patterns on an entire road network, and adapt traffic signals in order to maximize the capacity of the network as a whole. This was hardly a revolutionary technology, since it had been implemented widely around the world and in a few U.S. sites like Los Angeles and Montgomery County. However, Mobility 2000 researchers included it in their technical vision because it would support some of the other technologies, such as ADIS.

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In addition, ATMS would provide near-term and certain benefits, which made the vision more attractive to operating agencies. In order to win funding in the Highway Bill, Mobility 2000 would have to win support of entire FHWA and not just the research branch. However, the program branch of the FHWA was concerned with planning and implementing transportation technology rather than with researching it, and therefore Mobility 2000 had to include a technology promising immediate benefits. Traffic control technology could satisfy that concern. It was known to offer some benefits and would satisfy the interests of the key players controlling the Highway Bill.\textsuperscript{196}

However, including ATMS in the technical vision introduced a contradiction into the program: Mobility 2000 was proposing a technology development program, but ATMS was not a technology requiring technical development. ATMS was a technology requiring deployment. ATMS technology already existed, but as experiences in the 1980\textsuperscript{9} showed, the local DOTs who might use it lacked the skills and local funding to operate and maintain it. These problems would not be solved by any amount of technology research. Yet Mobility 2000 included ATMS in its technology development program in order to have an "early winner." The non-technical problem of skills in local DOTs had been treated as a technology research problem.

This tendency to treat deployment problems as technology development problems characterized the program generally. It reflected a tendency to interpret problems in a manner most compatible with sectoral institutions. The actors at the federal level had launched a technology development program; they possessed the expertise, resources, and jurisdiction to perform field tests of

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advanced technology. Promoting training and designing new funding sources at the local level -- solutions to the historic barriers to ATMS deployment -- did not match the federal resources. Instead, the problem was conceptualized in a manner compatible with available resources.

This tendency did not reflect an intent to deceive on the part of policy-makers. It simply reflected the composition of actors participating in the policy process. With numerous technical experts present in federal policy-making, technical interpretations of problems were regularly available. With very few local DOTs present in policy-making, their experiences with traffic management remained unknown or received little emphasis. It was hardly surprising that technical interpretations dominated the policy process.

The fourth and final system within Mobility 2000's technical vision was Commercial Vehicle Operations (CVO). CVO consisted of a smorgasbord of technologies for vehicle-roadside transactions. The most promising of these was electronic toll payment, whereby vehicles equipped with short-range transponders could exchange payment information with roadside toll stations, thereby eliminating the need to stop at toll booths. Such systems were being tested in a few toll plazas around the U.S. and firms were beginning to market them widely.

Thus the coalitional nature of Mobility 2000 had led to a coalition-like technical vision consisting of multiple systems corresponding to multiple interests. Ultimately the technical system manifested the sectoral institutions in the road transport sector. The vision-building process reflected the broad coalition needed to win support in the Highway Bill. Had the sectoral
institutions been different, then the technical vision would likely have been different as well. In Germany and Japan, where smaller coalitions were needed, the vision remained more focused. In the European Union and the EUREKA framework, where larger coalitions were needed, the vision was also broad.

The effect of institutions was not exclusively to broaden the vision: some systems failed to win support and so fell out of the ITS technical vision. For example, California researchers' work in electric vehicles did not match the interest of any other actor in the coalition and, as a result, that "system" was not included in the definition of ITS.\textsuperscript{197} Similarly, non-technical solutions to the problems of local traffic management systems were not included as part of the vision.

The activities of Mobility 2000 had been undertaken with the Highway Bill of 1990 in mind. By March 1990, when some two hundred people attended Mobility 2000's final meeting in Dallas, it seemed likely that a national program would be launched. Many of the key players had expressed support for the program, and Congress had even held hearings in June 1989 to learn about the technology.\textsuperscript{198} The technical vision of ITS was ready to be supported by the Highway Bill; the ITS program was ready to be launched.
Program Launch: Further Technology Design

Following Mobility 2000's conference in March 1990 the national ITS program was launched. The launch took place during the period from early 1990 until late 1991, when the new Highway Bill became law. Although scheduled for passage in 1990, it was not until December 1991 that President Bush signed the legislation, called the “Intermodal Surface Transportation and Efficiency Act” (ISTEA, pronounced "ice-tea.")

During the nearly two-year-long launch period, from March 1990 to December 1991, the national program was dramatically shaped by powerful political forces. The technology design was expanded, the program design was substantially reshaped, and a new organization called “IVHS America” was designed.

The changes imposed in this period reflected the interests of actors with power over the framework for funding. ISTEA, like other Highway Bills before it, was controlled by a well-defined set of actors including rural Congressional representatives and key committee chairs, AASHTO, HUFSAM, and the FHWA program branch. Each powerful actor left its mark on the emerging program.

This section recounts the reshaping of the ITS technology design during these two critical years. The following next sections recount how the design of new organizations and of the overall development program also adjusted to institutional forces. Table 7-2 shows a timeline for the U.S. program between 1990 and 1994.

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Table 7-2: Timeline of U.S. Activities, 1990-93

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Mobility 2000 Dallas Conference</td>
</tr>
<tr>
<td></td>
<td>HUFSAM Leadership Conference</td>
</tr>
<tr>
<td>August</td>
<td>ITS America incorporated (as IVHS America)</td>
</tr>
<tr>
<td>October</td>
<td>FHWA re-organizes</td>
</tr>
<tr>
<td>Fall</td>
<td>Advanced Public Transportation Systems added to ITS design</td>
</tr>
<tr>
<td>1991</td>
<td>Writing process for <em>Strategic Plan</em> begins</td>
</tr>
<tr>
<td>December</td>
<td>President Bush signs ISTEA into law</td>
</tr>
<tr>
<td>1992</td>
<td>Advanced Rural Transportation Systems added to ITS design</td>
</tr>
<tr>
<td>May</td>
<td><em>Strategic Plan</em> published</td>
</tr>
<tr>
<td>1993</td>
<td>First published list of projects</td>
</tr>
<tr>
<td>February</td>
<td>Four Priority Corridors designated</td>
</tr>
<tr>
<td>March</td>
<td>System architecture development begins</td>
</tr>
<tr>
<td>September</td>
<td>First draft of <em>Program Plan</em> completed</td>
</tr>
</tbody>
</table>

In 1990 as it became clear that an ITS program would come into being, a third agency within USDOT moved to join the supporting coalition. This agency was the Federal Transit Authority (FTA). The FTA did not want to miss out on what was shaping up as a large new federal program, so it proposed additions to the technical vision that would enable it to play a role.

In order to accommodate the FTA two changes were made. First, "driver" information systems were renamed "traveler" information systems. Drivers are only found in vehicles, but travelers include people using other modes such as mass transit. Traveler information systems would include consoles in homes and offices to inform people of current travel conditions. With a traveler information system, potential travelers at home could choose whether or not to begin a trip, and if so by which mode.

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A second change was the addition of an entire new system called Advanced Public Transportation Systems (APTS). APTS included driver information systems for transit drivers, electronic toll payment for transit vehicles, and a variety of other functions from the first four ITS systems applied to transit. The definition of an entire new system for transit applications reflected the underlying agency rather than the novel functionality. As another actor joined the coalition, another system was added to the technical vision. However, it seemed likely that such applications would prove useful, so the new system was accepted by the Mobility 2000 coalition.

Another system added to ITS raised numerous questions, however. This was Advanced Rural Transportation Systems (ARTS), made as a late addition to the ITS vision in early 1992. ARTS would include functions applied in rural settings.

As noted earlier, rural states exercised considerable influence in AASHTO and the Congress and thereby could affect which programs received funding through the Highway Bill. The ITS program hoped to receive support through that framework for funding, but their emphasis on traffic management and urban freeways gave the program a bias toward urban congestion reduction. In order to increase the proposed program's appeal to rural Senators, the technical vision was re-designed to incorporate a system matching the interests of rural DOTs. This system was ARTS.

Rural systems would include vehicle automation features to prevent rural drivers from running their cars off the road on monotonous highway voyages. The systems would also include a

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distress signal ("May-Day") for drivers whose vehicles broke down in a remote location. Some supporters suggested that systems might also warn drivers of deer in the road. No matter what their specific content, all rural systems had one crucial feature: they ensured that federal funds for ITS would flow to rural as well as to urban states.

More than any other system, the rural systems lacked a justification in anticipated benefits. Indeed, even within the research community supporting the program the addition of such systems proved controversial, and rural systems were initially rejected by the members of Mobility 2000. At a meeting in California in spring of 1992 one speaker announced that the rural systems proposal had been rejected as "too political." However, that decision was later reversed and rural systems were officially added shortly thereafter.\textsuperscript{199}

Thus, as the proposed program moved closer to winning funding, those interests with access to the framework for funding used their influence to shape development. In return for their support they received modifications to the technical vision that informed the technology design. As two latecomers joined the supporting coalition, two new systems were added to the ITS technical vision. The FTA received advanced public transportation systems, and rural interests received advanced rural systems. Ultimately, the six-part design of the ITS system provided a mirror image of the supporting coalition. Table 7-3 shows the relationship between actors and the ITS vision.
Table 7-3: The Coalition Supporting ITS, As Reflected in the ITS Technical Vision

<table>
<thead>
<tr>
<th>System</th>
<th>Corresponding Actor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Traveler Information System</td>
<td>FHWA research branch, FTA</td>
</tr>
<tr>
<td>Advanced Vehicle Control System</td>
<td>University of California, NHTSA</td>
</tr>
<tr>
<td>Advanced Traffic Management System</td>
<td>FHWA program branch</td>
</tr>
<tr>
<td>Commercial Vehicles Operations</td>
<td>Private firms</td>
</tr>
<tr>
<td>Advanced Public Transportation System</td>
<td>FTA</td>
</tr>
<tr>
<td>Advanced Rural Transportation Systems</td>
<td>Rural interests</td>
</tr>
</tbody>
</table>

One characteristic that was notably absent from the ITS concept was anything dealing explicitly with environmental concerns. ITS proponents had frequently justified their program by citing the expected environmental benefits. Yet when they defined their system, environmental functionality remained diffuse. With no environmental organization occupying a position of influence relative to the framework for funding, there was little pressure to include such a system. The rhetoric of environmentalism did not correspond to the institutions of the federal transport sector, so the words were never translated into action. This was later noted in a Congressional review of the program, which stated that "Among the objectives set forth by Congress, the one that seems to have received the least attention is the environment."200
Organization Design of ITS America

Events of 1990 and 1991 also affected organization design. In this period two major organization decisions were made in the ITS program. The first concerned the organization of the national forum for ITS developers, ITS America (originally named IVHS America), and the second concerned the internal organization of the FHWA. Again, in both of these design activities powerful players dramatically shaped development.

Mobility 2000 had not elaborated an organizational vision to match its technological vision. The coalition had noted that a "public-private partnership" would be needed in order to develop a system connecting vehicles and roads. Beyond that, however, little definition had been given to the organization of the national program.

The design of the organization for the program was performed by the leading interest groups in the transport sector rather than the ITS proponents. Shortly after Mobility 2000's Dallas meeting in March 1990, two leading interest groups in the road transport sector acted. They created a new organization to serve as the forum for all participants in the program. In so doing, they sought to win control of the emerging ITS program.

HUFSAM (Highway Users Federation for Safety and Mobility) and AASHTO (American Association of State Highway and Transportation Officials) were the two interest groups traditionally most active in highway policy. Together they had exercised enormous influence in transportation policy since before the Interstate Highway System, and their highway-building
approach had dominated transportation policy for decades.²⁰²

Of all the transportation policy-making organizations, HUFSAM had expressed the least support before 1990 for an ITS program. In the public sector, Congress, USDOT, and AASHTO had all expressed their commitment to ITS. In the private sector, however, HUFSAM had not made a strong public commitment. This was holding back the program, because in the Mobility 2000 vision of ITS the automakers would be the most important private sector partners, installing ITS technology in their vehicles. The automakers and HUFSAM would have to support ITS if the integrated systems concept were to succeed.

The reasons for this reticence lay in the poor match between the structure of HUFSAM and the new coalition emerging in support of ITS. HUFSAM's mission and membership only partially corresponded to the vision of the ITS program. HUFSAM was highway-oriented, but ITS crossed modal boundaries to include also transit and safety agencies. Furthermore, HUFSAM's membership did not include electronics or defense firms nor research universities, all of whom figured prominently in the ITS technical vision and supporting coalition. HUFSAM might emerge as a loser if a different association were created for ITS.

By 1990 HUFSAM was under pressure to act. Broad-based support existed for ITS and legislation for a program was pending. One of its most influential members, General Motors, supported the program. In response HUFSAM acted boldly. Instead of resisting ITS, it sought to bring the emerging program under its control. In May 1990, together with AASHTO and

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General Motors, HUFSAM hosted a conference in Orlando, Florida at which they proposed the creation of an organization for ITS development. At this "National Leadership Conference for Implementing Intelligent Vehicle Highway Systems," top-level administrators from nearly all the key organizations involved in national transportation policy voiced support for a national program. Public sector representatives included the U.S. Secretary of Transportation and the heads of the FHWA and AASHTO, while industry representatives included the head of HUFSAM and top-level representatives from General Motors, Motorola, and AT&T. HUFSAM had organized a meeting in which all the key players would come out in support of the launch of a national program.

At this conference HUFSAM presented a detailed proposal for the creation of a new organization to embody the public-private partnership needed for ITS. This organization, eventually named ITS America (originally IVHS America,) would serve as a framework for national coordination of all organizations, both public and private, interested in ITS. ITS America would be a loose umbrella organization joining federal, state, and local agencies, firms from the automobile, electronics, and computers sectors, and universities. It would serve as a forum where organizations involved in ITS activities could exchange information and learn from each other. Working together its members could determine a national program of research, define technical standards, and set priorities.

ITS America's status was two-fold. First, it was a public-private, non-profit, educational association (legally called a "501(c)(3)" organization.) Its membership would include

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representatives from government and industry and its focus would be on technology development, planning, and coordination. Its legal status forbade ITS America to engage in political lobbying (although its members were free to lobby on ITS issues elsewhere.) Second, ITS America would be a legally recognized "Utilized Federal Advisory Committee" to USDOT, which would allow it to provide policy recommendations to USDOT that could be adopted without further public review. This gave ITS America a special relationship to USDOT to make policy recommendations. In short, ITS America provided a focal point where a multitude of players with a multitude of interests could meet together and, to an as-yet-unknown-degree, could coordinate their activities. When the May 1990 National Leadership Conference was over, HUFSAM's organizational framework for the national ITS program was accepted. From being a minor participant in the movement to launch ITS, HUFSAM had assumed a leading role.

HUFSAM's action affected three aspects of the envisioned ITS program. First, HUFSAM's bylaws for the organization ensured that, together with AASHTO, it would exercise the most influence on the program. According to these bylaws ITS America would be a subsidiary organization of HUFSAM, and the position of President of ITS America would be automatically filled by the President of HUFSAM. Although ITS America would have its own Executive Director, the highest position belonged to HUFSAM. Furthermore, half of the new organization's top policy-making committee, the Board of Directors, would be reserved for HUFSAM and AASHTO members. Clearly, HUFSAM intended that it and AASHTO be in a position to exert strong influence in the new public-private partnership, just as they had in the Interstate Highway Program.
Second, HUFSAM sought to reduce the influence of the research community and to render the ITS program more operations-oriented. HUFSAM sought to achieve this by excluding researchers from the Board of Directors. HUFSAM's proposal for the membership of the Board left out some of the leading members of Mobility 2000. Members were mostly representatives of existing powerful players, like USDOT, HUFSAM, and AASHTO, as well as some communications firms like AT&T and Motorola. In contrast, no universities were included. They were instead relegated to the lower-level Coordinating Council. The academics were unhappy at this development. One academic captured the mood of his colleagues with his lament that "They stole our program!"\textsuperscript{203}

The final aspect of HUFSAM's actions was that ITS America was incorporated as a legally-recognized federal advisory committee. This formalized the relationship between outside advocates of ITS and the USDOT, for the outsiders now possessed a special status to participate in USDOT policy-making. ITS America possessed the leverage to insist on reviewing and commenting on planning and system development.

Thus the creation of ITS America was a large step forward for the national program, but one that also attempted to shape the emerging program. The private sector, represented by HUFSAM, had acted decisively to launch a public-private partnership. Yet in acting boldly HUFSAM had also boldly advanced its own interests. It had established a dominant position for itself in the national organization, controlling the top position of President and reserving for itself one-quarter of the Executive Committee. At the same time, HUFSAM had excluded the researchers in

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Mobility 2000 from positions of authority. Well-established actors in the transport sector were strongly represented on HUFSAM's Executive Committee.

Sectoral institutions had reshaped the ITS program -- at least temporarily. The subordination of the technical vision to the institutions of the transport sector manifested itself in the subordination of Mobility 2000 to AASHTO and HUFSAM. The technical vision was adopted, but only within existing frameworks.

HUFSAM's control over the emerging ITS program did not endure, however. First, universities demanded and won places on the Board of Directors. Threatening to resign as chairman of an ITS policy panel in the National Research Council, the first academic gained entry to that committee shortly after HUFSAM's May conference. Others soon followed, and the Board quickly became an open body with broad membership. In the two years following the incorporation of ITS America the by-laws were modified. The position of President was no longer exclusively reserved for the head of HUFSAM. Later, the reservation of a percentage of the Board for HUFSAM and AASHTO was repealed. By 1993 HUFSAM's position of control in ITS America was no longer guaranteed. It remained influential, but the advantages it had built into the structure of ITS America were eliminated.

Ultimately, HUFSAM's actions greatly strengthened the ITS program. Rather than oppose the program, HUFSAM had gambled that it could make it its own and threw its full weight behind it. The ITS vision was now supported by all the major actors in the transport sector.

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Organization Design in the FHWA

In October 1990 the FHWA reorganized to create a new structure for the coming ITS program. Here again the program was reshaped.

Although the ITS program was supported by other USDOT agencies, such as NHTSA and FTA, the lead agency for ITS development would be the FHWA. This was expected: the ITS proposal was championed by FHWA, many of the potential benefits were related to the FHWA's mission to serve traffic through provision of infrastructure, and the FHWA had the opportunity for a new, post-Interstate mission. In adopting the ITS program, the FHWA performed an internal reorganization and assumed leadership of a USDOT inter-agency coordinating committee. The internal reorganization centered around a new Office of Traffic Operations, which served as the focal point for FHWA activities.

Although some kind of new office had been expected within FHWA, the specifics of this reorganization departed from what many participants in Mobility 2000 had expected. With ITS having been defined and proposed by the FHWA research branch, it seemed likely that the program would be located in that branch. Yet in creating the new ITS office, the FHWA moved the locus of authority from the research branch to the programs branch. Two offices were created within FHWA. A smaller office in the research branch would oversee research and development, while a larger one in the program branch would serve as the central office for the entire national program.
This change represented an adaptation of the program to the existing division of labor. The difference between the existing structure of the FHWA, which featured greater power in programs, and the technical vision of ITS, which initially emphasized research, was resolved in favor of the existing structure. The FHWA was primarily an operational organization, planning highway construction rather than researching it. Within the FHWA the research branch was a much less influential group than the programs branch. With the ITS program being adopted as a follow-on to the Interstate, it was much larger than most research programs. Therefore, when it came time to define the organizational center of the new program, the program branch asserted its historically dominant position.

This organizational change also affected the program, shifting emphasis from research towards operations. The program branch was oriented toward near-term solutions to transportation problems. It began to emphasize near-term benefits rather than the ambitious technical vision of an integrated vehicle-roadside system of automated vehicles driving on optimal routes to their destination. This shortened time horizon first became visible in the definitions and names used by the FHWA. Once a new program office was created in FHWA, its title referred to "IVHS Applications." Thus even before ITS development had begun, the focus of the program had advanced from stage-two technical field tests (to investigate functionality) to stage-three operational tests (to investigate benefits of functioning technology.)

Although the technical vision adapted to the operations branch of the FHWA, it retained much of its content. The FHWA fully accepted the change in technology from civil engineering to

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information and communications. This technical change was quite radical, given that most agency members had made their careers building the interstate highway system. Furthermore, the public-private cooperation was also accepted. The FHWA would participate with ITS America.

Finally, the FHWA accepted the intermodal nature of ITS. The technology applied to all modes of road transportation, be it roads, vehicles, or transit. This stood in sharp contrast to USDOT's internal organization by modes and functions: the Federal Highway Administration was responsible for highways; the Federal Transit Authority was responsible for transit; the National Highway Traffic Safety Administration was responsible for road safety. The ITS program, however, would involve all these modes and would involve all these different agencies.
Congress Shapes the Program Design

Congress was the last of the major players to act on the ITS proposal. In late 1991, with a year's delay, Congress passed a Highway Bill, the $151 billion Intermodal Surface Transportation Efficiency Act (ISTEA). As ITS proponents had foreseen years before, this watershed bill provided the opportunity to launch the national ITS program.

The ITS portions of the ISTEA legislation provided $659 million of ITS funding over six years, and a second piece of legislation provided an additional $170 million for 1992 and 1993. Federal authorization for ITS over the next six years stood at $829 million. The U.S. finally had a national program for ITS development.

Although there had been some funding in the previous two years, with the passage of ISTEA funding had exploded. Congress had provided $2.3 million of funding for ITS-related projects in Fiscal Year 1990 (FY90). (A fiscal year in the U.S. government begins and ends three months before the calendar year.) In the next year, as Mobility 2000 stimulated greater interest for ITS, Congress provided $20 million funding for FY91. In FY92, however, with the passage of ISTEA together with generous annual appropriations, Congress provided the new ITS program with a whopping $234 million. From that year on, annual funding averaged over $200 million per year. The ITS program had begun with a bang, as federal funding grew by a factor of ten for two consecutive years. Table 7-3 shows the level of Congressional funding over six years, from 1990 to 1995. The high level of funding begun in FY92 continued on in following years.
Table 7-3: Funding of U.S. ITS Program

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Funding (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2.3</td>
</tr>
<tr>
<td>1991</td>
<td>20.0</td>
</tr>
<tr>
<td>1992</td>
<td>233.8 (ISTEA passed)</td>
</tr>
<tr>
<td>1993</td>
<td>143.0</td>
</tr>
<tr>
<td>1994</td>
<td>203.3</td>
</tr>
<tr>
<td>1995</td>
<td>227.5</td>
</tr>
</tbody>
</table>

Congress reshaped some aspects of the program to better match its structure of influence.

First, as noted, Congress authorized more funding for ITS than what had been expected. Mobility 2000 had proposed $100 million of funding per year. Congress had exceeded that number by nearly 40%, providing $138 million per year. Eventually, the program settled at some $200 million of federal funding per year.

Second, one key Congressman created an entire new category of ITS activity and allocated the majority of program spending for it. Senator Frank Lautenberg of New Jersey chaired the Senate's Appropriation Sub-committee on Transportation and Related Agencies, a position giving

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him powerful influence on transportation legislation. He created a "Corridors Program" for demonstrating and implementing ITS. Although the Corridors Program was reshaped in the House of Representatives, it did survive the legislative process. Of the $659 million in ISTEA, fully $500 million was reserved for the Corridors Program, half in four "Priority Corridors." In addition to New Jersey, three other Priority Corridors were designated near Houston, Los Angeles, and Chicago (one north, south, east, and west.) The Corridors Program emphasized ITS applications and operational testing; research and development would be covered by the remaining non-Corridor funding.

A third and related modification made by Congress was to earmark funds for particular Congressional districts. Earmarking is language in legislation that requires specific amounts of funds to be spent on particular projects in particular locations. Most of the ITS funding was earmarked. The pattern of earmarking reflected the pattern of influence of different states. The state with the most earmarked funds was New Jersey, with some $64 million for fiscal year 1992 (FY1992). Members of Congress from other states, although not so well-positioned as their colleagues from New Jersey, were also able to earmark funds. Michigan Representative Robert Carr, Chair of the House Appropriations Subcommittee on Transportation, earmarked over $11 million for Michigan in FY1992.

A number of other details in the ISTEA legislation targeted specific aspects of the program. One of these was to provide support for the most research-oriented areas of the ITS vision, those for automatic vehicle control. This part of the legislation was added by the House Science and

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Technology Committee, where California Representative George Brown occupied an influential position. Since the main proponents for vehicle automation research were in the University of California, this emphasis on research coincided neatly with distributional interests in the House. Again, however, the emphasis was on demonstration rather than pure research. Congress defined an Automated Highway System and required that USDOT demonstrate a prototype system by 1997. The prototype would consist in some form of "hands off" driving, possibly on specially reserved highway lanes.

Defense industry interests also influenced the legislation. With reductions in defense spending occurring around 1991, some Congressmen saw an opportunity for defense labs to apply their capabilities to civilian technology. Senator Pete Dominici of New Mexico included language requiring the use of national laboratories in the ITS program where possible. Both located in New Mexico, Sandia and Los Alamos national labs needed new funding opportunities to support their technical expertise.

Thus Congress reshaped the national ITS program in adopting it. The program design changed: spending increased and emphasis shifted to the third stage of development (operational tests.) Both of these changed were consistent with the framework for funding. ISTEA facilitated growth in spending because it was itself so very large, authorizing $151 billion in transportation spending. The ITS program's $659 million of funding was only a small part of that larger bill. However, those $659 were much more public funding than any other program in the world. Overseas
programs had access to less funding because they were supported by frameworks for funding for technology development rather than for operational funding.

ISTEA also promoted a shift in emphasis in the program from research to demonstration. Mobility 2000's vision had included research, technical field tests, and operational tests, but with an emphasis on advanced technologies for traveler information and vehicle control. By earmarking large amounts of funding for operational tests, Congress changed the program's focus to one of operational tests. Through earmarking and the Corridors Program, important technical decisions were also made, for technology development decisions were constrained by the conditions and capabilities of the designated state DOT's. Since these DOT's were less interested in research and more interested in near-term solutions, the program's emphasis moved toward applications.

However, even as Congress imposed conditions, it also expanded funding beyond the initial vision. Research and technical field tests still received significant support. Operational tests simply received more funding.

In summary, as it adopted the ITS proposal, Congress substantially modified the program. Congressional actions manifested the forces in the Highway Bill. Funding increased, and the relative emphasis shifted to stage-three operational tests.
Program Spending Priorities and Planning

By the beginning of 1992 the program was up and running. The technical vision had been modified to accommodate additional players, most notably rural and transit interests. The new organization ITS America had been created and the FHWA program branch had assumed control of the program. Congress had increased overall program spending, had earmarked much of the funding for projects across the country, and had shifted emphasis to operational tests.

With the program incorporating influences from many different actors, it was complex and multifaceted. A top priority of the FHWA in the early years was to impose coherence on the multitude of activities. This section summarizes the program and its first three years of activities from 1992 through 1994.

By 1992 there was not yet a coherent plan by USDOT, the FHWA, or ITS America on how to use the funds. Although Mobility 2000 had published a vision of ITS, no concrete plan existed yet for what the ITS program would look like. ITS America, founded before ISTEA even passed as law, had begun drafting a plan. However, it was not published until May 1992.

With its earmarks Congress had raced ahead of ITS advocates in USDOT, industry, and academia. The lack of a plan had given Congress a free hand to earmark funds for pet projects proposed by different state DOTs. The actions of Congress showed the danger of not having a plan: distributional politics had been unconstrained by technical judgment.
The creation of an overall plan for the U.S. program was a top priority in 1991 and 1992.

Between July 1991 and May 1992 ITS America produced the *Strategic Plan for Intelligent-Vehicle Highway Systems in the United States.*209 This was a national plan representing the consensus view of what ITS (then IVHS) was and what actions needed to be performed to realize the ITS vision. It sought to define the goals and objectives of the program, the activities to be pursued, and the roles of the different players.

On the one hand, the *Strategic Plan* was remarkable in that it represented the hard-won consensus of hundreds of firms, public agencies, and universities. On the other hand, the document offered considerably less detail that similar planning documents from programs overseas. Both the DRIVE *Workplan* and the PROMETHEUS *Topics of Research* contained more technical detail in their definition of specific technologies for research and demonstration. The *Strategic Plan* did not present official figures of committed spending by either USDOT or industry. It was a broad consensual document. Still, it remained an enduring statement of the guiding vision and overall strategy of the U.S. national program.

In December 1992 the USDOT also published its own *Strategic Plan*. This document outlined the roles and responsibilities of the different agencies within USDOT. By not simply adopting the ITS America plan, USDOT made it clear that it had its own program independent of ITS America.

Following publication of the two strategic plans, both ITS America and USDOT attempted to
write more detailed plans. These plans were to set priorities for funding. However, the consensual process used in ITS America was ill-suited for decisions determining financial winners and losers in the program. ITS America's "tactical plan," which it began writing in mid-1992, foundered on the issue of funding and priorities, and before it could be completed the effort was abandoned. Instead, USDOT undertook this more tactical activity with its Program Plan. The results were quite similar, however. The Tactical Plan also did not contain clear spending priorities.

Ultimately, no plan could include well-defined research topics and priorities for funding. Instead program spending was set largely through a combination of political process and planning process. The political process operated through earmarks. Ultimately, earmarks applied to nearly fifty percent of all program spending. However, the FHWA exercised discretion over a significant percentage of program funds. It exercised its technical discretion in selecting operational tests for ITS development.

In addition to transportation-related earmarks, Congress made special efforts to channel ITS funds to the defense industry. In August 1993 USDOT and the Department of Energy (DOE) entered into a Memorandum of Understanding to use the national laboratories' defense technology expertise in the ITS program. The fruits of these and other agreements could be seen in the more technologically-advanced parts of the ITS program. Twenty defense contractors were among the recipients of $33.3 million funding for Automated Highway Systems to realize "hands off" driving. Ten defense contractors received most of the $20 million to develop the
ITS system architecture. By 1994 fifty defense firms were members of ITS America, fully one out of every ten members.211

The effect of the defense sector on the ITS program in the U.S. differed greatly from the effect of the technology ministries in Europe, Germany, and Japan. Overseas, technology ministries provided support to commercial firms to develop systems for civilian markets. In the U.S., defense firms and national laboratories consumed resources.

Thus central planning of program spending remained imperfect. Congressional earmarks, special Corridors, and defense firms support all contributed to fragmentation. At the same time, central planning did go forward. A single national association had been created; two related strategic plans had been written; and the FHWA was overseeing operational test selection.

In some program reviews the tendency toward fragmentation attracted notice. Two external reviews of the program called for increased central oversight over projects. In December 1994 the Inspector General issued a program audit of the ITS program delivery process. It noted that the program management and oversight controls required improvement to ensure effective project selection and monitoring. Then in October 1995 the Congressional Budget Office of the U.S. Congress recommended that the ITS program might seek to improve the process of setting priorities and selecting projects. The report notes, "Funding is divided among several hundred projects, including some that appear to duplicate others and some that have not been"
designed to produce clear-cut results." "... too much duplication is wasteful and risks turning a research program into a pork barrel."\textsuperscript{212}

Although they identified weaknesses in the program, such evaluations did not address the underlying reason for the lack of control in the program. The problem lay in the framework for funding, the ISTEA Highway Bill. ISTEA was controlled by a broad set of actors who brought many concerns about continued transportation spending.

Here, national as well as sectoral institutions affected outcomes. At the sectoral level, the end of the Interstate had determined the timing of the follow-on program, and the very large number of earmarks reflected states' interest in continued federal transportation spending. However, the vulnerability of the process to the dynamics of pork barrel spending reflected a weakness of all U.S. technology policy. In these early years of the program both sectoral and national institutions affected outcomes.
The ITS Program: Technology Emphasis

The content of the ITS program was technology development. Although many actors influenced spending priorities, the results were consistent in their emphasis on technology. All projects sought to apply advanced technology to transportation.

The activities of the ITS program fell into two broad categories: development projects and overall system integration. Development projects were numerous and diverse. System integration activities were the responsibility of the FHWA.

Technology development activities fell into three categories. First, Research and Development (R&D) projects consisted of experiments of system components. These included such items as the use of the subcarrier of the commercial FM broadcast band to transmit digital traffic information, electronic fare card technology, and the setting of performance specifications for collision avoidance systems. The biggest activity in this category was the Automated Highway Systems development program, which sought to develop fully automated vehicle driving technology. These activities corresponded mostly to stage one (research) and stage two (technical field test). By February 1993 there were nearly 100 projects funded in this category.213

A second category of activity was Operational Tests. According to program documents, "Operational tests bridge the gap between R&D and full scale deployment ... to evaluate advanced systems in real world situations ..."214 The Pathfinder, Travtek, and ADVANCE

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operational tests resembled smaller-scale versions of the CACS test in Tokyo and LISB test in Berlin. Other operational tests performed motor vehicle regulatory inspections (ADVANTAGE -75) and managed bus fleets (Denver Smart Bus). By June 1994 some 43 Operational Tests were underway.\textsuperscript{215}

A number of operational tests involved joint investment by government and industry. Firms like General Motors and Motorola, who had been among the earliest champions of a national program in the days of Mobility 2000, developed commercial products and participated in federally-funded operational tests. From 1990 to 1994 General Motors participated in a field test of vehicle-roadside communication system in Orlando, Florida, called Travtek.\textsuperscript{216} Motorola participated in a similar field test in Chicago, Illinois.\textsuperscript{217} These firms also developed and marketed in-vehicle navigation devices. Throughout the program private firms were active in many aspects of ITS development.

Finally, the program included four Priority Corridors, the brainchild of the U.S. Senate rather than USDOT. These were geographic locations where much operational testing and early-stage deployment would have to occur. Most importantly, 50\% of all program spending would have to be disbursed in these locations. Much of this funding, however, took the form of Operational Tests in the Corridor location.

A major reason for the technology development orientation of the program lay in the funding restrictions imposed by ISTEA. USDOT was specifically barred from using ITS program
funding for deployment: "Federal [ITS] funds have been devoted to the development and operational testing of specific user services and technologies, but are not currently available for the general deployment of [ITS] infrastructure. Infrastructure deployment is currently progressing with funding through Federal-Aid programs such as the National Highway System…" The ITS community in ITS America chafed at this restriction, but could not change it. A report commissioned by ITS America in 1993 noted the need for deployment of ITS and recommended federal funding for deployment: "Major progress toward deployment will depend upon legislative assurances of long-term funding for [ITS] infrastructure." However, such funding could not be obtained. ITS remained a development program.

The second set of activities in the U.S. program were system integration and central planning. Despite its expansiveness and fragmentation, the ITS program was at the same time a highly centralized and planned activity. This reflected the governance structure in the road transport sector.

The governance structure from the Interstate Highway System carried over into the ITS program. The FHWA had long exercised authority for national system planning in the Interstate Highway System, and this same authority was transferred to the ITS program. In 1991 the FHWA had assumed a formal leadership role in the ITS program when it was named the "lead agency" in USDOT.

Further centralization in the FHWA occurred in 1994. The central role of the FHWA was
reinforced by the creation of a Joint Program Office (JPO). The JPO was a new office created to exercise oversight over the entire program for all of USDOT. The JPO was located within the FHWA. Thus the FHWA possessed the authority needed to perform central planning in the program.

Through the Joint Program Office (JPO) the FHWA performed two activities for central planning. These were the writing of the Program Plan (described above) and the commissioning of a system architecture development. Both these activities gave coherence to the national program. Both were also conducted with assistance from ITS America, thereby assuring that interests outside of USDOT had a voice in the planning process.

From the earliest days of Mobility 2000 great importance had been placed on the concept of a national system with a system architecture. In part this was an adaptation of the technology design to the framework of funding: ITS had to be a national system if it was to receive federal funding. However, nation-wide compatibility of components also made sense both for long-distance drivers and for the industries hoping to serve national markets. The first official recommendation of ITS America to USDOT, therefore, had been to develop a national system architecture. A system architecture would define the functional boxes and their interconnections of an overall system, providing enough definition that independent suppliers could independently develop components that would then fit together.

The approach recommended by researchers in ITS America was that of a military system
development project. Multiple teams of technical experts would competitively develop rival concepts which would be evaluated and accepted or rejected. Beginning with four teams, two would be eliminated after a first round, and the final two would jointly develop a system architecture. In this process, the emphasis was on technical expertise: the four teams were each headed by a defense contractor with expertise in complex system development.

Through this project the FHWA sought to gain control over the program as a whole. In the future, should federal financing become available, it could be made contingent on compatibility with the system architecture. This in turn would ensure that different cities and states could be coaxed into deploying systems compatible with systems elsewhere.

In the design of the system architecture the U.S. program surpassed all other ITS program in the degree of centralization achieved. One national agency oversaw a top-down development process for a unified system. The governance structure in transport allowed the FHWA to design a single architecture. Although national institutions had led to an opening of the program to participation by many parties, sectoral institutions in transport simultaneously allowed for centralization.
Outcomes of Development

Of all programs examined, the U.S. program has the shortest history. Furthermore, since it is not yet complete, one cannot yet talk of final outcomes, but only of intermediate outcomes. Still, the effect of sectoral institutions can be clearly discerned in the intermediate outcomes of the program in 1994. The technology design, program design, and organization design all manifested sectoral institutions.

The technology design mirrored the division of labor in USDOT and the distribution of power in the road transport sector. The original six systems corresponded to six players in the road transport sector, as shown in Table 7-3. The absence of some other systems also reflected the absence of players in the program. Most notably, the lack of an environmental system, despite the rhetoric, reflected the absence of any such player in the sector.

The existence of a national system architecture was made possible by the governance structure in the road transport sector. The FHWA possessed authority for nationwide system planning for the Interstate Highway System, and this authority carried over to the ITS program. The U.S. was the only program with a governance structure suitable for the development of a system architecture.

It was in program design, however, that institutional effects were most pronounced. The high level of funding and its distribution across the U.S. reflected the distribution of power among Congressional representatives situated in powerful positions for the Highway Bill.
Furthermore, the shift in emphasis in the program toward operational tests reflected these powerful actors’ concern with benefits.

Finally, the organization design sought to bridge gaps across existing institutions where the ITS technical vision defined linkages. The JPO bridged gaps across the modal agencies within USDOT, and ITS America bridged gaps between USDOT and industry and academia.
Chapter 8

CONCLUSIONS

This concluding chapter consists of two parts. The first part considers outcomes achieved by 1995. The outcomes of the five ITS programs are compared, and the sectoral institutions model is used to explain the differences among them. The second part of the chapter focuses on the model of sectoral institutions, summarizing the model and the research strategy used to develop it. It offers the lessons and theoretical insights of this study.

ITS programs had three types of outcomes by 1995. The first of these was technology design, which refers to the functions included in the system and to the presence or absence of a system architecture. The second outcome was the program design, which refers to the funding and relative emphasis given to the different stages of development. The third outcome was organization design, which refers to the form of new or modified organizations. The next sections summarize and compare those outcomes, showing how differences reflect the influence of sectoral institutions. We begin by examining technology design.
Technology Design

All ITS programs began with a similar technical vision. However, their final technology designs differed. The original technical vision can serve as a baseline against which to measure the degree of change in the outcomes. In some programs the final design closely matched the original technical vision, while in others it differed considerably. Although the differences cannot be unequivocally evaluated as “better” or “worse,” they can be identified and their causes explained.

Technology design refers to two things: the functions included in the system and the system architecture. We begin by examining functionality.

Functionality

The U.S. program and the European DRIVE program produced systems with a range of functionality that exceeded the original ITS technical vision in ERGS. The Japanese program and the Siemens’ program in Germany produced systems whose functionality closely matched that technical vision. The European PROMETHEUS program produced a technology design whose functionality was less than the original technical vision.

The greatest range of functionality could be found in the U.S. system design with its six different functional areas (traffic management, vehicle automation, traveler information, commercial operations, transit, and rural applications.) This broad functionality reflected the framework for funding. A broad range of the actors participated in the coalition for ISTEA (the Highway Bill of 1991.) Ultimately, the technology design reflected the coalition formed of three USDOT agencies

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(FHWA, NHTSA, FTA), two research programs (FHWA and University of California), and powerful rural interests in the highway community. Figure 7-3 in Chapter 7 related the different functional areas to these coalition members.

The DRIVE Program of the European Commission's Directorate General (DG) XIII also produced a broad technology design. Again, the framework for funding contributed to this. A broad coalition of European Union member states controlled DRIVE's framework for funding.

In contrast to these two programs, the technology design in PROMETHEUS offered relatively less functionality. European automakers in PROMETHEUS initially pursued a system vision, but later they reduced their design to autonomous in-vehicle devices. Here, the framework for funding initially supported the system vision, but the governance structure in European transport later inhibited it. The EUREKA framework for funding had supported development in the research stage. However, with no actor possessing pan-European authority for transport infrastructure, automakers could later find no partner for the "road" component. They adapted their technology design to those domains where they possessed authority, developing only in-vehicle devices. Although they continued to emphasize the desirability of a vehicle-roadside system, they could not actually achieve it.

Finally, two programs were noteworthy for how closely their technology design conformed to the original ITS vision. After decades of development Siemens' ALI-SCOUT and the Japanese VICS program both deployed systems that realized the ERG's technical vision of a vehicle-roadside

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communication system. These programs' technology design neither expanded functionality, like the U.S. design, nor reduced it, like the PROMETHEUS design. Both programs employed frameworks for funding controlled by smaller coalitions than in the U.S.; this protected them from the need to unnecessarily expand their technology design. Furthermore, both programs assembled the full range of authority needed to deploy their systems; this avoided a need to reduce their technology design.

Institutional effects in the Japanese system manifested themselves in redundant functionality. Shared governance in transportation by the Ministry of Construction and the National Police Agency led to two functionally similar systems using different media. The bifurcation of CACS into RACS and AMTICS was a dramatic manifestation of how governance structures could shape technology design. Although RACS and AMTICS were later joined into a single system, VICS, the redundancy in the communication media remained.

The outcomes of Siemens’ program and the PROMETHEUS program differed markedly. Siemens achieved systemic functionality, while PROMETHEUS did not. This difference reflected the division of labor. Siemens possessed expertise in all components of the system and could single-handedly develop ITS. Automakers could not develop their system without the active participation of public authorities, which they failed to obtain. Admittedly, Siemens’ go-it-alone made the firm somewhat vulnerable, for other actors might reach consensus on an incompatible standard and thereby leave the firm isolated. Nonetheless, its very ability to develop the full system was a unique achievement reflecting the firm’s broad expertise.

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Thus the five ITS programs ultimately developed quite different technology designs. Table 8-1 presents the differences and some of the underlying institutional causes.
<table>
<thead>
<tr>
<th>Program</th>
<th>Technology Design</th>
<th>Sectoral Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>More fns</td>
<td>FF: Broad coalition required</td>
</tr>
<tr>
<td>DRIVE</td>
<td>More fns</td>
<td>FF: Broad coalition required</td>
</tr>
</tbody>
</table>
| PROMETHEUS| Less fns          | GS: No European road authority (Hence, no coalition possible)  
|           |                   | DL: No infrastructure expertise (Failed to build full coalition) |
| Siemens   | Original fns      | FF: Narrow coalition required              |
|           |                   | DL: Expertise in all components (Hence, small coalition req'd) |
| VICS      | Original fns      | FF: Narrow coalition required              |
|           | Parallel fns      | GS: Shared authority (MOC,NPA) (Leads to parallel coalitions) |

**Sectoral Institutions**

DL: Division of Labor  
FF: Framework for Funding  
GS: Governance Structure
System Architecture

The second aspect of technology design was the system architecture. The system architecture was the blueprint that defined the functions to be performed by system components and the connections between them. Here again outcomes varied.

Two programs produced a system architecture. The first of these was the U.S. program, which had made significant progress by 1994 toward realizing a comprehensive system architecture. This reflected the governance structure in the U.S. road transport sector. In the U.S. the national governance structure of transport placed authority in a single agency, the FHWA. As a result, the idea of a national system architecture received emphasis from the earliest days of the program, in part because it served the FHWA’s interest in launching a national program. This sectoral institution made it possible to attain a higher degree of integration than in overseas programs.

Siemens also developed an overall system architecture. With the entire system under the control of a single firm, system-wide planning was easily achieved. The resulting system architecture was highly integrated; ALI-SCOUT could not even function unless both in-vehicle devices and roadside infrastructure were in place. Only a system developed by a single entity could embody such a tightly integrated architecture. Here the division of labor, which concentrated expertise in one firm, allowed for central system design.

DRIVE initially emphasized the system architecture concept as well. However, the fragmentation of governance in European transport soon led to the abandonment of the idea. Instead, European

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ITS advocates adopted as their goal the promotion of interoperability between different systems developed at the national level. With no single entity overseeing development, a single architecture proved unfeasible. The vision of a system architecture simply did not correspond to the fragmented governance structure of European transport.

In Japan governance structures also created barriers to a coherent system architecture. At the national level, Japan was late in even beginning the process of developing a system architecture. Only with the creation of the pan-Japanese VERTIS organization in 1994 did effective nationwide coordination become possible. However, because of the autonomy of government ministries, inter-ministerial coordination was difficult. The situation of the five ministries joined in VERTIS resembled that of the many national governments in Europe; their traditional independence made cooperation difficult. No national authority existed for all ITS-related activities. No substantive progress toward a system architecture had been made by 1994.

Finally, PROMETHEUS developed no system architecture. Instead automakers participated in DRIVE activities for coordination.

Table 8-2 shows the different system architectures and relates them to sectoral institutions.

Together with the differences in functionality in Table 8-1, the two tables summarize the influence of sectoral institutions on technology design.
### Table 8-2: Technology Design: System Architecture

<table>
<thead>
<tr>
<th>Program</th>
<th>System Architecture</th>
<th>Sectoral Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>Yes</td>
<td>GS: Single national road authority</td>
</tr>
<tr>
<td>Siemens</td>
<td>Yes</td>
<td>DL: Siemens does entire system</td>
</tr>
<tr>
<td>DRIVE</td>
<td>Inter-operability</td>
<td>GS: No pan-European road authority</td>
</tr>
<tr>
<td>PROMETHEUS</td>
<td></td>
<td>(Pursued through DRIVE)</td>
</tr>
<tr>
<td>Japan Nat'l</td>
<td>Late</td>
<td>GS: Multiple ministries</td>
</tr>
</tbody>
</table>

**Sectoral Institutions**

- DL: Division of Labor
- FF: Framework for Funding
- GS: Governance Structure
Program Design

The second outcome of development was the program design. Program design referred to two aspects of the development program: the size and pattern of spending in the program and the relative emphasis given to different stages of development. (As described in Chapter 4, the four stages of development in ITS were research, technical field test, operational test, and deployment.)

The curious intermittent history of ITS development in the U.S. reflects the framework for funding in the road transport sector. ITS development started early, then stopped in 1971, then started again twenty years later. What most explains these dynamics is the status of the Interstate Highway construction program: only once that earlier program finished would the FHWA be ready to launch a major new program.

When the ERGS proponents sought funding for technical field tests they were turned down in 1971, for the players controlling transport funding were occupied with the construction program. Not until the Interstate was finished could the first steps be made toward a new program. Finally in 1991 the framework for funding presented an opportunity. With the Highway Bill open to a new initiative and the FHWA seeking a follow-on mission, the ITS proposal was adopted.

The inactivity in the intervening twenty years reflected the absence of an alternative framework for funding. Overseas ITS advocates could take their proposals to their ministries of technology. U.S. advocates had no such alternative. In 1971 U.S. development simply ceased.

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When the framework for funding in the transport sector finally did finally open for a new initiative, the magnitude of funding reflected the magnitude of ISTEA. The U.S. government funded ITS development at $200 million per year -- much more than overseas programs. However, within ISTEA, this was a small amount -- less than 1 per cent of federal transportation spending. The fact that public funding in the U.S. was larger than overseas programs reflected its status as the only program funded in the context of highway construction rather than technology development.

Thus the magnitude of funding from the late 1960s through 1995 reflected the available frameworks for funding. The budget of the research branch of the FHWA was sufficient for the early research in ERGS. No framework for funding existed for follow-on to ERGS, and as a result spending dropped to zero. Finally, with the first post-Interstate Highway Bill (ISTEA), funding shot up to $200 million per year.

In addition to shaping funding levels, ISTEA also shaped the emphasis given to different stages of development. The actors controlling highway funding modified the program to match their concern for operational activities. Policy-makers added a large number of operational tests and "Corridors" that promised more near-term benefits. Even the most advanced research topics were transformed by the stroke of the legislators' pen into operational tests: the ISTEA legislation required a demonstration of an automated highway by 1997, although the technology was far from being able to demonstrate benefits. Thus by funding technology development through the

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Highway Bill, the ITS program design came to emphasize operational tests.

Outside of the U.S., different frameworks of funding were available. ITS programs began with technology funding rather than transportation funding. Technology-oriented frameworks for funding included MITI (for CACS), EUREKA (for PROMETHEUS), DG-XIII (for DRIVE), and the German Ministry of Research and Technology (for ALI-SCOUT). Because all the other programs were supported by frameworks for funding for technology, they shared some common experiences.

To begin with, all overseas programs received funding for stage-one research and stage-two technical field tests. With appropriate frameworks for funding available, their program designs could fund these early stages of development. This provided a striking contrast to the U.S., which lacked an appropriate framework for stage-two technical field tests.

All overseas programs experienced difficulties in the transition to later stages of development. Frameworks for technology funding covered the first two stages. Programs then had to make a transition to frameworks for transportation funding. This transition usually caused years of delay.

DRIVE got off to a strong start with technology research funding from the European Commission's DG-XIII. With millions of dollar budgeted for research, DRIVE could pursue a variety of topics. However, the framework for funding imposed distributional forces that caused DRIVE to spread resources thinly. With thinly-spread funding, DRIVE could perform only

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research. It could not advance to technical field tests, because such tests required more concentrated funding. Despite expert recommendations by internal auditors to concentrate its resources in a few large technical field tests, DRIVE continued performing research.

Compounding this problem was the lack of any appropriate framework for funding in transport. Neither funding nor authority for transportation infrastructure development existed at the European level. Thus DRIVE could not gain access to transportation funds. DG-XIII did manage to tap into the Structural Funds available for less-developed member states. This, however, meant that activities had to be located in countries like Portugal and Greece, which had less need for such advanced infrastructure. Just as the U.S. program found itself funding rural systems, DRIVE found itself performing tests in southern European countries.

PROMETHEUS also got off to a strong start, thanks to funding from the EUREKA framework. Like DRIVE, however, PROMETHEUS could not advance to operational tests of the system concept. In order to move forward automakers had to adapt to the limited available resources. They narrowed their focus to the vehicle, where they possessed authority for development. This strategy allowed them to advance to operational tests of in-vehicle devices. By the end of their program in 1994 PROMETHEUS had developed useful stand-alone products. Because automakers possessed authority and funding for in-vehicle technology, they were not completely stymied by the lack of pan-European governance in transport.

In Germany the Ministry of Research and Technology (MRT) served as a framework for funding

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for Siemens, allowing it to perform a technical field test in Berlin. Although that funding was not subject to strong distributional forces, Siemens did have to allow its rival Bosch to join as a partner. When Siemens later advanced to operational tests and deployment, it too confronted the indifference of transport authorities. However, Siemens’ expertise in all aspects of ITS enabled it to develop the system by itself.

Finally, the Japanese development program benefitted from an initial technology framework for funding that imposed few distributional forces. Like LISB in Berlin, CACS in Tokyo was comparatively free from distortions caused by coalition-building. However, the program design was dramatically distorted at the operational test stage due to the governance structure in transport. The NPA and the MOC split the development program in two. Later VICS uneasily reunited the development program.

Thus the five ITS programs manifested quite different institutional effects in their program design. Only the Siemens program in Germany and the VICS program in Japan passed sequentially through the four stages of development. Because the U.S. program received funding from the operations-oriented Highway Bill, it immediately emphasized stage-three operational tests. DRIVE and PROMETHEUS were both hindered by the lack of pan-European transport authority. DRIVE continued a focus on research, while PROMETHEUS advanced just in the vehicle.

Tables 8-3 and 8-4 summarize the effects of sectoral institutions on program design. Table 8-3
shows programs' relative emphasis on different stages of development. Table 8-4 shows their relative spending levels.
<table>
<thead>
<tr>
<th>Program</th>
<th>Stages of Development</th>
<th>Sectoral Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>Stage 3 big</td>
<td>FF: Highway Bill requires benefits</td>
</tr>
<tr>
<td></td>
<td>Stage 1 &amp; 2</td>
<td>FF: Strong distribution forces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FF: Enough funds for research, too</td>
</tr>
<tr>
<td>DRIVE</td>
<td>Stage 1</td>
<td>FF: DG-XIII supports technology</td>
</tr>
<tr>
<td></td>
<td>No stage 2</td>
<td>FF: Strong distribution forces</td>
</tr>
<tr>
<td></td>
<td>No stage 2, 3</td>
<td>GS: No European transport authority</td>
</tr>
<tr>
<td>PROMETHEUS</td>
<td>Stage 1</td>
<td>FF: EUREKA supports technology</td>
</tr>
<tr>
<td></td>
<td>No Stage 2</td>
<td>GS: No European transport authority</td>
</tr>
<tr>
<td></td>
<td>Stage 2 &amp; 3</td>
<td>DL: Develop in-vehicle devices only</td>
</tr>
<tr>
<td>Siemens</td>
<td>Stage 1 &amp; 2</td>
<td>FF: German MRT supports technology</td>
</tr>
<tr>
<td>ALI-SCOUT</td>
<td>Stage 3 &amp; 4</td>
<td>DL: Siemens can develop full system</td>
</tr>
<tr>
<td>VICS</td>
<td>Stage 1 &amp; 2</td>
<td>FF: MITI supports technology</td>
</tr>
<tr>
<td></td>
<td>Stage 3 twice</td>
<td>GS: Multiple ministries (MOC, NPA)</td>
</tr>
<tr>
<td></td>
<td>Stage 4</td>
<td>GS: Centralized authority</td>
</tr>
</tbody>
</table>

(DL: Division of Labor  
FF: Framework for Funding  
GS: Governance Structure)

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### Table 8-4: Program Design: Public Funding

<table>
<thead>
<tr>
<th>Program</th>
<th>Amount and Distribution</th>
<th>Framework for Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>$200m / year Distributed</td>
<td>Transport: Larger sums Broad coalition</td>
</tr>
<tr>
<td>Total '92-95</td>
<td>$810 million</td>
<td></td>
</tr>
<tr>
<td>DRIVE '89-92</td>
<td>$ 24m / year Distributed</td>
<td>Technology funding</td>
</tr>
<tr>
<td>DRIVE '92-95</td>
<td>$ 30m / year Distributed</td>
<td>Technology funding</td>
</tr>
<tr>
<td>Total '89-95</td>
<td>$162m</td>
<td>Broad coalition</td>
</tr>
<tr>
<td>PROMETHEUS</td>
<td>$ 32m / year</td>
<td>Technology funding</td>
</tr>
<tr>
<td>Total '87-94</td>
<td>$224m</td>
<td></td>
</tr>
<tr>
<td>ALI-SCOUT</td>
<td>$6.5m total</td>
<td>Technology funding</td>
</tr>
<tr>
<td>LISB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe '87-95</td>
<td>$ 48m / year</td>
<td></td>
</tr>
<tr>
<td>Europe '87-95</td>
<td>$392.5m total</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CACS '73-79</td>
<td>$ 86m total</td>
<td>Technology funding</td>
</tr>
<tr>
<td>RACS/AMTICS</td>
<td>$ 25m total</td>
<td>Transportation budgets</td>
</tr>
<tr>
<td>Japan '73-90</td>
<td>$ 7m / year</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$111m total</td>
<td></td>
</tr>
</tbody>
</table>

Figures do not include investment in:
- Installed infrastructure (e.g. existing traffic management)
- Future deployment (esp. ALI-SCOUT/COPILLOT and VICS).
Organization Design

The third outcome of development was organization design. New organizations bridged the old institutional boundaries. Some organizations overcame the fragmentation of expertise resulting from the division of labor; others overcame the fragmentation of authority resulting from governance structures; still others overcame the fragmentation of funding from different frameworks for funding.

Most organizations were designed to overcome the division of labor and to unite actors with complementary expertise. In the U.S. two national organizations were created, ITS America and the Joint Program Office (JPO) in USDOT. ITS America was the national association that served as the forum for all public and private participants in the U.S. development program. Its members came from industry, academia, and federal, state, and local government. The JPO was an inter-agency office to coordinate the activities of agencies within USDOT. ITS America and the JPO both facilitated communication and cooperation between actors participating in development.

ITS America also served as a platform for groups pursuing federal funds from ISTEA. With $200m per year budgeted to the ITS program, many firms joined the association in order to learn how to get a piece of the federal spending. Since ITS America was incorporated as a so-called "501(C)3" educational non-profit corporation, it was legally barred from engaging in formal lobbying activity. However, such a restriction proved of little significance in practice. ITS America offered instructional seminars on how to bid for federal contracts. Furthermore, member organizations like defense firms, automakers, and electronics firms coordinated their...
lobbying for ITS the program. The leading ITS trade journal consistently referred to ITS America as an “advocacy organization.”

Overseas, similar inter-ministerial and public-private coordination was achieved in VERTIS in Japan and in ERTICO in Europe. Created in 1994, VERTIS sought to define a single forum for all ITS organizations. The VERTIS Inter-Ministry Council brought together five Japanese ministries, while the VERTIS Japan Promotion Council brought together industry and subsidiary associations. These two organs of VERTIS were associated with each other to create the public-private linkage.

Organization design in Europe addressed a more fundamental problem than the fragmentation of expertise. The design of ERTICO sought to overcome the fragmented authority in the transport sector. ERTICO attempted to be a single body for Europe-wide deployment decisions. ERTICO sought both to unite expertise and authority. However, it attracted more of a technical membership than a political one; authority remained in the many national ministries.

The problem of governance spawned organization re-design as well. To create pan-European authority for transportation infrastructure, ITS advocates supported modifications to existing organizations. First, the Directorate General (DG) VII for Transport expanded its mission to include infrastructure and technology development. In the 1992 Maastricht Treaty on the European Union a new domain of authority was defined for DG-VII. The treaty defined a "Trans-European Network" in transportation and gave DG-VII authority to help plan and

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coordinate its development. Then in 1995 DG-VII was given a budget for technology
development. In part these moves sought to redesign DG-VII to better match the needs of ITS.

New organizations also bridged the gaps between frameworks for funding. Here the gaps were
temporal, appearing when one funding source ended before another began. The JSK association
in Japan bridged the gap between early MITI funding and later NPA and MOC funding.
Following the CACS technical field test, MITI created JSK to nurture interest and knowledge in
ITS until development could continue in the transport sector. JSK kept ITS alive in the time gap
between stage two and stage three in development.

Operating organizations had to assemble an enduring combination of expertise, funding, and
authority. By the mid-1990s both VICS and Siemens were advanced enough to create operating
organizations. The VICS design embodied a strategy of partnership. Different actors possessing
complementary resources joined together in partnership in the VICS Council.

In contrast, Siemens’ COPILOT Corporation worked around existing institutional boundaries,
realizing the entire system through a industry partnership. COPILOT pooled private capital and
did not include any public sector participants, achieving a purely private organization to plan,
deploy, and finance ITS.

Automakers in PROMETHEUS did not have to establish new organizations to market their in-
vehicle devices. Their technology remained within the boundaries of existing organizations.

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Although technologically innovative, the devices did not require the design of new operating organizations to realize new linkages among actors. However, Daimler-Benz's Intertraffic subsidiary did join with Siemens in the COPILOT industry consortium.

Thus organizations designed for the various ITS programs bridged the gaps in the organization of resources. New or re-designed organizations created linkages to join expertise, authority, and funding.

To summarize this first half of this chapter, outcomes of the five parallel ITS programs around the world varied in the design of their technology, their program, and their organizations. As ITS developers built coalitions, exploited opportunities, and worked around obstacles, ITS development came to reflect underlying institutions. A few sectoral institutions explain many of the variations in outcomes in programs.
II. The Model of Sectoral Institutions

This second part of this chapter presents this study's contribution to knowledge of large technical system development. We address the following questions:

1. What is the model of sectoral institutions?
2. Were appropriate means used to develop this model?
3. What lessons are offered?
4. What is the theoretical contribution of this study?
5. What further research is possible?

We begin with the first question.

The model of sectoral institutions was explained in Chapter 3. Figure 8-1 (which reproduces Figure 3-3) shows the model.

Large technical system development begins with a technical vision. The technical vision defines the components and their interconnections into a system, and it defines a series of stages of development. The technical vision can be “unpacked” into a matrix with its components on one dimension and its stages of development on the other. It is an analytical tool to better understand what the development of a particular large technical system entails.

The realization of the technical vision requires three types of resources: expertise, authority, and funding. Development requires expertise in the components and in system integration to realize the technical vision. It requires authority in the domains needed to test and deploy systems in the
different stages of development. And it requires funding to pay the costs of development at each stage. The technical vision matrix indicates which resources will be needed. Much of the activity of system developers, particularly at the policy level, is the acquisition of these resources.
Figure 8-1: Full Model of Sectoral Institutions

1. Technical Vision
   - Matrix in 2 dimensions:
     1. system components
     2. stages of development
   - Resource Needs:
     expertise
     authority
     funding

2. Sectoral Institutions
   - Division of labor (expertise)
   - Governance structure (authority)
   - Frameworks for funding (funding)

3. Development Process
   - coalition building
   - resource creation

4. Outcomes of Development
   - program design
   - technology design
   - organization design
Sectoral institutions structure resources. They define the available resources and the actors
controlling those resources. There are three kinds of sectoral institutions. The division of labor
defines what expertise exists and which actors possess that expertise. Governance structures
define what domains of authority exist and which actors possess that authority. Frameworks for
funding define what funding exists and which actors control those funds.

System development, which consists largely of the acquisition of resources, is shaped by sectoral
institutions. Developers must first locate institutionally-defined resources, and then they must
build the coalition of actors possessing those resources. In so doing, the development process is
shaped.

When needed resources exist, then development proceeds as coalition-building. Developers must
assemble the coalition of actors that control the needed resources. Actors’ interests figure
prominently in this process: development must serve (or at least not damage) the interests of
actors if they are to join the coalition. The need to satisfy actors’ interests shapes the program.

When needed resources does not exist, then development may also be affected. Development
may fail altogether (as happened to ERGS in 1971.) Development may be distorted as it seeks
resources from less appropriate sources (as in DRIVE’s use of Structural Funds for field tests in
southern Europe.) Or the resource may be created (as in the creation of ERTICO as a pan-
European governance body.)

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The outcomes of development are technology design, program design, and organization design. Ultimately, these outcomes bear the imprint of the sectoral institutions. They reflect the presence or absence of needed resources, as well as the number and interests of actors in the coalition. The first half of this chapter summarized how sectoral institutions shaped the outcomes of the ITS programs.

As discussed in Chapter 3, the model of sectoral institutions facilitates understanding and explanation. However, it also has some ability to allow for prediction and intervention. These aspects of the model are discussed next.
Prediction

The sectoral institutions model offers some predictive ability. Based on an analysis of the technical vision and the sectoral institutions, combined with some heuristics about effects, some aspects of the outcomes can be predicted. Prediction is based on the availability of resources and the coalitions controlling resources.

The relationship between resource needs and resource availability allows for two, very simple predictive heuristics. First, when a needed resource does not exist, then some likely outcomes can be predicted. Second, when a resource exists, then some likely outcomes can be predicted by examining the coalition controlling those resources.

When a needed resource simply does not exist, three effects are likely: delay, distortion, or termination. First, program will likely be delayed if system proponents create the missing resource. Development may have to wait while expertise, authority, funding is specially created. For example, to correct for the lack of pan-European authority in transportation, ITS proponents in Europe created ERTICO. This took years to accomplish.

Second, missing resources may also distort development. If a resources is absent and cannot be created then the system may be redesigned so that the resource is no longer needed. For example, automakers in PROMETHEUS adjusted to the lack of pan-European transport authority by redesigning their system to be autonomous of the roadside. This revised design could be realized without public authority. In another example, the U.S. had no framework

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for funding for second-stage technical field tests like LISB in Berlin or CACS in Tokyo. The U.S. program worked around it, by advancing immediately to stage-three operational tests. With no funding for technical field tests, the development skipped a stage and advanced to operational tests in transportation organizations around the country. These field tests sought to simultaneously reduce both technical uncertainty (stage 2) and organizational uncertainty (stage 3).

Finally, missing resources may lead to the termination of a program. ERGS was terminated in 1971, arguably for lack of an appropriate framework for funding. Unlike in Japan and Germany the U.S. did not have available funding for large scale technical field tests. Furthermore, in 1971 operational funds were not available either. Development failed altogether.

A second kind of prediction becomes possible when a resource does exist. Prediction here is based on the particular characteristics of groups controlling the needed resource.

The simplest heuristic here is based on the number of actors controlling a resource. When a large number of actors control a resource, then the need to satisfy many interests is likely to shape and possibly distort the program. This was most apparent in the frameworks for funding in the European Union and in the U.S. Funding there was controlled by many actors, and this introduced many distributional concerns that distorted programs. The U.S. program and DRIVE conducted many more field tests than other programs, because they had to build

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such large coalitions in order to obtain the needed funding.

More detailed prediction is possible, but it requires knowledge of the particular coalition controlling a resource. The final heuristic is that system development will reflect the interests of the coalitions that control resources. The exact way that development will accommodate interests depends on the particular coalition. Although no generalizeable prediction can be made, it can be predicted with likelihood that interests will be reflected in outcomes. Technology design and program design (especially funding) will reflect those coalitional needs.

All these observations can be condensed into the following predictive heuristics:

1. If a needed resource is absent, likely outcomes are:
   - Delay - development must wait as missing resources are created.
   - Distortion - development is reshaped to eliminate the need for the resource.
   - Failure - development is abandoned for lack of a resource.

2. If a needed resource exists, the interests of the set of actors controlling the resource will affect outcomes. The larger the set of actors controlling resources, the more likely it is that interests will distort development.

Clearly, these heuristics are of limited predictive power. Yet even this limited power can offer valuable insights.

Using these heuristics, a cautious prediction can be made about the U.S. ITS program after 1995. The U.S. lacks resources needed for deployment. As a result, the program is likely to be delayed or distorted -- or even to fail.

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ITS deployment requires expertise in information technology in local transportation organizations. However, in the U.S. that expertise does not exist. In Japan and Germany, such expertise does exist: local transportation operating organizations have installed computerized traffic control systems in those countries over the past twenty years and, in doing so, have created operating expertise in computer technology. In the U.S. traffic control systems were not widely installed, so the accompanying expertise was not developed.

Furthermore, in the first five years of the U.S. ITS program little effort was made to train local operators; the focus was on technology rather than on skills.

This missing resource will make deployment difficult and even unlikely. Deployment will not proceed as envisioned without expertise at the local level. Three outcomes are likely. First, deployment may be delayed as local skills develop. To do this, training programs may have to be created and simple, well-established applications may have to be deployed. A national program of traffic control system deployment may have to be launched, as was done in Japan in the late 1960s. One can image that five or ten years might pass before a local agency could begin to deploy more advanced technology.

Alternatively, development might be distorted as systems are designed to work around the missing resources. Instead of vehicle-roadside communications, ITS applications may use vehicle-satellite communications; these would not require expertise in local organizations.

Finally, the national program may have so much difficulty with deployment that it could be

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declared a failure. Attempts might be made to deploy advanced technology, only to have it fall into disuse for lack of adequate local skills to operate and maintain it. After a few such failures, the national program could be terminated altogether.

We predict that the U.S. program will develop toward a combination of these. The public sector will shift its priorities to the deployment of established technologies and the training of local staff. A trend toward this was already discernible in the announcements by the Secretary of Transportation in January 1996.²²²

Thus, the model of sectoral institutions offers some predictive capabilities. Although limited, these may still offer insights into the likely outcomes of development and can suggest action strategies for developers.
Practical Techniques for Intervention

The model of sectoral institutions also offers insights that can inform practice. These are techniques for intervening in large technical system development. These techniques are most likely for use by mid- to upper-level administrators in public agencies and corporations. However, they are also relevant for analysts and for public interest activists concerned with the social impacts of large technical systems.

By facilitating understanding about resource needs and the organization of resources, this model helps practitioners recognize the challenges confronting development. By facilitating understanding of coalition-building, this model helps them formulate effective strategies for development. By showing how developmental outcomes are the product of coalition-building, this model helps them make informed choices during negotiations.

Many social science models either emphasize free human action and neglect social structures, or they emphasize structure and neglect human action. A particular strength of this model is that it offers a structural account of development that does not deny the importance of human action. The model illuminates constraints, not to reveal the futility of human action, but to promote more effective action. The words of Durkheim, quoted in Chapter 2, bear repetition here: "It is difficult for man to have to renounce the unlimited power over the social order that he for so long ascribed to himself... Repeated experiences have in vain attempted to teach him that this all-powerfulness ... has always been for him a cause of weakness; that his dominion over things only really began when he recognised that they have a nature of their own..."223

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The techniques offered here complement those in the existing literature. Depending on their theoretical approach, authors emphasize either structure or action. On the one hand, the institutional literature offers lessons about institution design. Cohen and Noll suggest the creation of new Congressional committees with a framework for funding for technical field tests and operational tests.\(^{224}\) McNaugher suggests restructuring the development process to encourage appropriate competition.\(^{225}\) On the other hand, writers in the process literature focus on coalition-building. Vincent Davis identifies political techniques by which innovators build coalitions with colleagues, superiors, and organizational outsiders.\(^{226}\)

The lessons from this study combine those two approaches, informing action in the context of structure. Like Davis, we focus on coalition-building. But as institutionalists, we focus on structural factors in the coalition-building process. We offer four practical techniques for developers of large technical systems:

1. analysis of the technical vision,
2. analysis of the context,
3. formulation of strategy of coalition-building, and
4. tools for coalition-building.

Most of these techniques are familiar from the previous discussion of the model and from the case studies.

The first technique is the analysis of the technical vision. System developers must first understand their goal, the technical vision. They can achieve this understanding by analyzing the technical

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vision using the concepts of the technical vision matrix. By "unpacking" the technical vision, they can better understand what they have set themselves to do. The technical vision matrix, described briefly in this chapter and in greater detail in Chapters 3, is a two-dimensional representation of large technical system development. From this analysis developers can begin to recognize the resource requirements of their technical vision. These resources have also been described earlier. They are expertise, authority, and funding.

By translating a technical vision into a set of resource requirements, system developers attain a better understanding of the tasks of development. Following this analysis development can be understood as the activity of acquiring needed resources. Developers can now recognize the task before them.

The second technique is the analysis of the context. This identifies the needed resources. Here the concepts of sectoral institutions enhance understanding. By examining the division of labor, developers can identify players with the needed expertise. By considering governance structures, developers can identify relevant domains and the actors that exercise authority in them. By examining frameworks for funding, developers can recognize where funding is available and which actors control it.

The analysis of the context allows for an additional translation of the technical vision. The first analysis, immediately above, translated the technical vision into a set of resource requirements. This second analysis translates it into sets of actors. Development can now be understood as the

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activity of building a coalition of these actors. Through this further translation developers gain a better understanding of the task before them. The goal of developing a large technical system is reconceptualized as the goal of assembling a coalition.

The third technique is the creation of a strategy for coalition-building. This involves identifying actors to enroll in the coalition supporting development. The context of development may contain more resources than are needed: there may be multiple frameworks for funding or multiple actors with the needed authority or expertise. Different actors controlling similar resources may have different interests. As a result, it may be easier to win the support of some than of others. One actor may be looking for a new project, while another is currently busy with another activity. Developers can invest their energies in winning the support of actors whose interests render them most likely to join the coalition. Although they operate in a structured environment, developers can exercise a degree of freedom in assembling coalitions.

In formulating a strategy, developers may follow some simple heuristics. They may seek to minimize the number of actors in their coalition. Smaller coalitions may prove more stable than larger coalitions. Developers may also seek to avoid coalition-members whose interests are not served by the technical vision. Actors with bring extraneous interests may introduce unpredictable demands on development.

The fourth technique relates to coalition-building. Numerous techniques may attract actors into coalitions, as the case studies showed. These include: education, designing the technology and
program, and waiting.

The simplest technique for coalition-building is outreach and education. The system developer explains the vision to the needed parties in the hope that they will support it. Every developer in every ITS program spent considerable time publicizing the vision. Outreach and education can be best performed through some small task. For instance, the desired coalition-members may agree to participate in a small task or a small study. In this way, they become educated in issues, relationships develop, and commitment builds.

As the ITS case studies illustrated, technology design and program design are also techniques for coalition-building. Program design refers to the size and distribution of funding. Clearly, actors may be convinced to support development by the provision of funding. Changes to the technical vision to create functionality appealing to actors’ interests is another coalition-building technique. The case studies provided many illustrations of this.

Another important, if simple, technique is waiting. Actors’ interests change over time. Developers may have to wait for actors who control resources to have an interest in their technical vision. Sometimes an entrepreneur must wait years before a suitable opportunity arises for actors to support development. For example, after the termination of ERGS nearly twenty years passed before the vision could be proposed again in the U.S.

MITI illustrated one practical technique for waiting. In order to wait for an opportunity to
transfer its CACS technology to road transport organizations, it created the JSK Association. The JSK Association was an important tool to survive the waiting period and to avoid losing the knowledge gained in CACS.

Another way of winning partners is to modify the technical vision to serve the interests of the needed coalition members. In the U.S., rural systems were added to ITS in order to serve the interests of politically powerful rural groups. Much of this study showed how differences in outcomes reflected adaptations made according to actors' interests.

The degree of malleability of the technical vision may facilitate coalition-building. The ITS technical vision proved remarkably malleable; for every new party, a new system could be added. Such all-inclusiveness would not have been possible with a different technology. Had the Space Shuttle been designed with as much accommodation as occurred with ITS, it might never have risen from the ground (although NASA's accommodations did eventually cause a Shuttle failure.\textsuperscript{227}) ITS's malleability allowed new features to be added at will, linked together in a single loosely-coupled system.\textsuperscript{228}

Finally, organization design provides another technique for development. When no actor exists with all the needed resources, an organization can be created within which the set of actors can meet, communicate, and coordinate actions.

These techniques for analyzing the technical vision and context and for building coalitions

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constitute the lessons of this study. They are practical tools to guide action within a structured environment.
The Research Design

In this study we have formulated and then tested a hypothesis about large technical system development. That hypothesis was: *sectoral institutions affect outcomes of large technical system development*. This is a causal hypothesis in which the explanatory variable, sectoral institutions, affects the dependent variable, the outcomes of development.

That hypothesis was investigated through a cross-national comparison of parallel development programs. Five ITS programs were examined (or six, if the original ERGS program is counted separately from the later U.S. program.) Most variables in development remained constant across programs. However, the explanatory variable (sectoral institutions) did vary. By observing how the dependent variable (outcomes) varied, the hypothesis of causality could be supported or falsified.

The ITS programs were well-suited for this logic of investigation. Many variables did not change across programs. All programs had a nearly identical technical vision, and all programs involved the three same sectors (automotive, road transport, and communications.) Yet the explanatory variable, sectoral institutions, varied. Furthermore, the dependent variable, the outcomes, also varied across cases. This combination of similarity and difference in cases made it possible to isolate the explanatory and dependent variables to a high degree and to infer how the former affected the latter.

Still, some readers may feel that the case studies were not fully appropriate for comparison.

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These criticisms deserve acknowledgment here.

First, no program was fully complete, and two programs were still quite far from completion. Those two, DRIVE and the U.S. program, were still conducting research and various field tests. Therefore, it may not yet be appropriate to talk about final outcomes for these two programs. However, the other three systems were nearly complete: Siemens’ ALI-SCOUT and the Japanese VICS systems were starting deployment by 1995, and PROMETHEUS terminated in 1994. ERGS had also run its course by 1971. Still, with programs not fully complete, it must be acknowledged that the comparisons are not as appropriate as they would be with less contemporary programs.

Second, comparison between national programs (in the U.S., Japan, and Germany) and international programs (in Europe) may also be a cause for objection. Some readers might dispute whether any meaningful comparison can be made between a single nation and a multinational union. Readers can judge for themselves whether the comparison with the European Union in this study makes sense. Both ITS practitioners and the author of this study felt that the EC’s DRIVE program did not exhibit many qualitative differences from other programs. In fact, the U.S. program resembled DRIVE more than the German or Japanese programs.

Another possible point of objection could be the differences of scale in programs. One might claim that the resources available to a program performed by Siemens, for example, are necessarily less than those available to a program performed by U.S. government and that the two

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cannot be meaningfully compared. Yet this study has sought to explain those very differences in scale. In a different institutional context, the U.S. program might well have turned out like the Siemens program: a coalition of General Motors, Motorola, and university researchers might have received federal support to perform a technical field test on the scale of LISB in Berlin. Thus differences in scale do not preclude comparison; rather, they require comparison in order to be explained.

Nor do differences in scale reflect responses to the demands of different-sized populations or economies. Except at the deployment stage, technology development need not respond to such factors. Technology development produces knowledge, answering such questions as, Does a system function and have benefits? The pursuit of knowledge is not more expensive in larger countries than smaller countries. Only the cost of nation-wide deployment differs; it costs more to deploy systems in every city in the U.S. than in every city in Germany. Such deployment costs, however, have not been compared here. This study's comparison of development costs before deployment is appropriate.

A fourth and final criticism is particularly relevant to this study. A comparison of similar activities in similar sectors in different nations is at the same time a cross-national comparison. This means that an important variable cannot be held constant in cross-sectoral comparison: the nation state and its institutions also vary between case studies. Observed effects, therefore, may reflect variation in national institutions rather than variation in sectors.

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This is unavoidable. Since no single nation contains two instances of the same sector, comparison across similar sectors involves comparison across nations. Nonetheless, that does not rebut the criticism.

National-level institutions clearly influenced the outcomes of programs. They mostly influenced the size of the coalitions controlling frameworks for funding. Most top-level funding decisions took place in legislatures and were shaped by national political institutions. Still, national-level institutions could not explain all aspects of programs. That the U.S. was the only program to develop a centralized system architecture contradicts the logic of the decentralized institutions of the U.S. government. That the Japanese program split into two rival programs contradicts the logic of the centralized Japanese state.

Two alternative research strategies do exist for comparing sectors within nation states, but these also suffer from problems. The first is to compare large technical system development in different sectors within the same national political system. In this way national-level institutional variables are held constant. However, this causes other variables to change. In varying the sectors, the technical vision in each sector will vary. Were the ITS program to be compared to, say, the breeder reactor program in the energy sector, the outcomes might reflect variations across the two technical visions. In holding national-level variables constant, new variation appears elsewhere. Once again, the sectoral-level institutions are no longer perfectly isolated.

A second strategy is to compare the same sector within the same nation state but at different

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points in time. In this strategy, both national-level and technology-level variables could be held constant. However, it is unlikely that the same technology would be developed twice in the same sector at different points in time.

Interestingly, the same ITS technical vision was pursued twice in the U.S., once in 1970 in ERGS and again in 1991. Thus it has been possible to use this strategy of cross-historical comparison to complement the dominant cross-national strategy. The two ITS programs in the U.S. had very different outcomes. These differences cannot be explained by cross-national or cross-sectoral differences, but by the institutions of the transport sector itself. As explained above, the framework for funding in the road transport sector (the Highway Bill) presented no opportunity for a program in 1970 but did present one in 1991. Thus the cross-historical comparison strengthens the other findings of the study. By itself, however, it would not have yielded as many insights as the cross-national comparison that comprises the bulk of this study.

This research design of cross-national sectoral investigation has many precedents. In his study of the social construction of missile guidance systems, for instance, Donald MacKenzie compares activities in the Soviet Union and the U.S. Based on this cross-national comparison he explains differences in trajectories of technology development by differences in the sector-level contexts of each development program. Other studies have performed cross-national comparison in order to investigate sector-level "policy networks." Studies have examined such sectors as chemicals and pharmaceuticals in Germany, France, and the United Kingdom. As J. Nicholas Ziegler notes in reference to this literature, "State power clearly varies across sectors, and even highly centralized

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states must rely on external networks in important cases.\textsuperscript{231} Through cross-national comparisons, these studies illuminate sector-level phenomena. This study employs the same research design, although it poses different research questions.\textsuperscript{232}

No one strategy of inquiry can avoid all problems of research design. For this reason it makes sense to complement any one approach with some of the others. MacKenzie, whose main method is the single case study (a particularly problematic research strategy), includes smaller complementary cross-national and cross-sectoral comparisons. Similarly, this study of ITS complements its cross-national comparison with a smaller cross-historical comparison of the two U.S. programs of 1970 and 1991. This two-pronged strategy of comparative inquiry provides the basis for the conclusions offered here.
Implications for Theory

This study also attempts a scholarly contribution to the literatures reviewed in Chapter 2. The scholarly contribution of this work relates primarily to theories of large technical system development. In particular, it relates to “technology-push” programs in which technologists pursue a technical vision (in contrast with “market-pull” programs, in which solving an existing problem is paramount.) However, this study also relates to larger political science debates over institutions. The relevance to large technical systems and to political science literature on institutionalism are considered in turn.

Relative to Hughes' system approach, the sectoral institutions model differs in two important respects. First, whereas Hughes rejects disciplinary reductionism, this study does not. Hughes' high-level concept of a seamless web encompasses all aspects of development, from science, to economics, to politics, and so on. In contrast, this model of sectoral institutions is unabashedly reductionist, reducing the messy and complex reality of system development down to a few simple concepts and relationships. In particular, this model emphasizes structural factors in development over human agency and entrepreneurialism.

The author does not defend this reductionism on the basis of claims to truth. The model of sectoral institutions is not the one true model of system development that reduces reality to its essence. Rather, the validity of this reduction lies in its utility in practice. The author claims that the concepts and relationships elaborated here can make a difference in the practice of system development; therein lies their validity. To paraphrase Richard Rorty's paraphrase of John

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Dewey, our knowledge of the worlds does not work in practice because it is *true*; rather, we hold our knowledge to be true because it *works* in practice. The model of sectoral institutions offers a set of concepts with which to interpret and simplify the messy complexity of the world, and this reductionism has practical value. Other interpretations of the world, even interpretations at odds with this one, may also have practical utility, and they are also true insofar as they work in some manner for those that would use them. Thus, the reductionist approach used here is not incompatible with Hughes' holistic systems approach, for the reductionism is grounded in practice rather than in truth claims.

Second, the sectoral institutions model allows deeper understanding of some of Hughes' own concepts, most notably that of "momentum." Old systems have momentum, leaving a residue that can give rise to new systems. The sectoral institutions model allows for deeper understanding of what momentum is and how it occurs. Much of the residue of previous large technical systems is embodied in frameworks for funding, governance structures, and the division of labor, and these define the institutional context for later initiatives. Old systems may leave behind an environment rich in resources, so advocates can more easily assemble the resources and the coalitions needed for follow-on systems. With its narrow but deep study of sectoral institutions, the reductionist approach used here allows for a finer understanding of what momentum is and how it unfolds.

If the product of this study is more reductionist than the systems approach, it is far richer and complex than another approach, that of the rational actor. The rational actor approach takes reductionism to a higher degree, reducing the complexity of the world to a unitary actor with

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ordered goals, well-defined choices, and relationships of cause and effect. A great deal of empirical data is eliminated when this model is applied.

Of course, the rational actor model is *prescriptive* rather than *descriptive*, so it would be inappropriate to evaluate it exclusively on the basis of its empirical correspondence. The rational actor model justifies itself by its practical utility. Few models offer comparable power as a guide for practical action.

Yet the model of sectoral institutions achieves a high degree of practical utility without a comparably extreme degree of reduction. The lower degree of reduction is evident in the additional features incorporated in the model. First, development is acknowledged to unfold in a highly-structured context that shapes choices and actions; the sectoral institutions define this context. Second, development is recognized as a social process involving multiple actors with multiple interests who must join together to act; this multiplicity is manifested in the process of coalition-building. Corresponding to these additional features are practical techniques. Techniques for analyzing the technical vision and the institutional context allow practitioners to understand the opportunities and barriers present in their structured context. Techniques for identifying and assembling coalitions allow practitioners to engage in multi-party action. Thus, the sectoral institutions model accepts the criterion of practical utility as the measure of its value as a model, without having to "assume away" the complexity of large technical system development.

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Sectoral institutions can also provide insights that go beyond those of the process approach typified by the writings of Trevor Pinch, Wiebe Bijker, or Vincent Davis. Clearly, the sectoral institutions model is closely related to the process perspective; both emphasize coalition-building among interested actors. The difference is that the sectoral institutions model allows for a deeper understanding of what coalitions are needed and what coalitions form. The analytical concept of the technical matrix helps translate the system vision into a set of resource requirements; these resource are what the developers pursue. The analytical concepts of the three sectoral institutions reveal the structure of available resources and the actors that control them; system developers must enroll these actors in a coalition in order to obtain the resources. Together, these concepts allow for reconceptualization of system development in terms of coalition-building. By conceptualizing system development in terms of resource needs and institutionally-defined resource availability, this model reveals the underlying factors that shape process. With these factors recognized, the process of system development and coalition-building is more comprehensible.

This increased comprehension also allows for more effective practice. Some writers in the process approach, most notably Vincent Davis, offer practical techniques for coalition-building. The sectoral institutions model offers additional insights into analysis and strategy-formation that complement such techniques for coalition-building. Using the sectoral institutions model system advocates can understand the resources needed for their technical vision, and they can scan their environment for appropriate frameworks for funding, governance structures, and sources of expertise. With this information they can formulate a strategy of which groups should be targeted.
for coalition-building efforts. Thus this model helps practitioners to better understand their tasks and to formulate strategies for the development process.

The final body of theory to which this study makes some contribution is that of the institutional approach to large technical system development and to political science. Since the model here itself works within this approach, this discussion is more detailed than with the previous approaches.

Relative to existing institutional literature, this study makes two contributions. First, in the broad literature on the "new institutionalism" in political science, this study offers evidence of the role of institutions in political processes. Institutional effects permeated the different ITS programs. The model here identifies institutions that structure the relationships between actors and that shape processes. The historical residue of previous programs, particularly in the governance structures and the division of labor, powerfully affected the different development programs. The model shows how and why state power may vary across sectors, and how "weak states" may still be capable of central planning when lower-level structural features allow it. Although this study has focused on large technical system development, its findings bear some relevance for public policy in general. Many public policies require such resources as funding, authority, and expertise, and the insights of the sectoral institutions model can illuminate them as well.

Second, and more specifically, the sectoral institutions model offers insights that go beyond those offered by a focus on just national institutions. These differences are in the perspective of analysis.
and the institutional effects identified.

The perspective of this study has been that of the system developer. Most studies of institutions emphasize the set of institutions in question and only secondly the particular policies and programs that unfold within those institutions. Typical of this approach, the works by McNaugher and by Cohen and Noll focus on one set of institutions and document their effects on a variety of system development programs. The question that they ask is, Are U.S. federal institutions well-suited for technology development policies?

The emphasis in this study has been the reverse. This study has focused on the actions of agents within institutions, rather than on the institutions themselves. Thus, although the study offers an institutional model, it considers institutions from the perspective of system developers. The question here is, "If one is advocating development of a large technical system, how does one analyze the institutional context, formulate a strategy, and carry forward development?" By tracing out how five different programs pursued the same vision through five different contexts, we gain insight into how a variety of institutions shape development.

From this perspective, the distinction between different institutional levels is less significant. From the developers' perspective, local, regional, national, and pan-national institutions are comparable insofar as they offer resources needed for development. This point is reminiscent of Hughes' observation that system developers do not respect disciplinary boundaries; here, the point is that developers do not respect institutional levels. For system developers, what matters

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about institutions is how they organize the resources needed for development. That availability depends more on sectoral boundaries than on institutional levels. When developing a system for transport, it is more significant that funds or authority or expertise apply to transport than that they reside at the local or national level.

One strength of this perspective is that its practical insights include the ability to compare and select between institutions. In technology development policies, the same technical vision might be pursued in the public sector, at the federal or state levels, or in the private sector. The U.S. ITS community discussed at length whether ITS should be implemented by private firms or by public agencies. From the perspective of the system developer, these may all be potential sources of resources distinguished only by the different sets of actors that control them. This equation of public and private institutions and of national and local institutions may violate disciplinary boundaries. Yet from the perspective of the system developer, these boundaries may be of little practical significance. This model's common treatment of different institutions in terms of resources and coalitions renders it a practical tool for evaluating different institutional contexts as potential sites for development.

Thus, the sectoral institutions model is not completely different from the national-level institutions model of other writers on large technical systems. National-level institutions figure in this model, most often as frameworks for funding. The Highway Bill that launched the ITS program was written in the context of the U.S. Congress, and the effects of this framework for funding also embodied the effects of U.S. political institutions. Yet other institutions in the transport sector

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figured prominently as well. The governance structures of transport influenced development, as
did the distribution of expertise. Any study that by definition focuses on national institutions risks
overlooking the importance of these other institutions.

Attention to a broader range of institutions within a sector captures the variety of institutional
factors that shape developers' actions as they pursue their technical vision. And this broader
attention allows for useful practical techniques, such as choices between alternative frameworks
for funding.

But do other institutions really matter? Does attention to expertise and governance structure
explain anything not explained by an exclusive focus on national political institutions? We argue
that they do matter.

First, the effects of sectoral institutions are visible where national institutions exercise less
influence. National-level institutional theories say more about countries whose institutions are ill-
suited to technology development policies, such as the U.S. In contrast, Japanese national
institutions allow bureaucrats to make technically sound but unpopular decisions. There, the
impact of institutions on technology development policy is less marked.

However, ITS development in Japan was not free from institutional effects. Sectoral institutions
affected the Japanese ITS programs: the lack of unity in the governance structure of transport
counteracted the unity of the Japanese state. Initially, MITI's CACS technical field test provided

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evidence of the ability of the national government to develop technology. However, as
development advanced that unity was undermined by the divided governance over road traffic by
the Ministry of Construction (MOC) and the National Police Agency (NPA). The strength of
each bureaucracy in Japan made for strong bureaucratic turf wars between them. ITS, which
crossed multiple bureaucracies' jurisdictions, could not be developed by any one organization, and
bureaucratic rivalries inhibited joint action. Thus in a "strong state" lower level institutional
effects may still play a large role.

The contrary effects of sectoral institutions were also apparent in the U.S. program. National
institutions cannot explain why the U.S. was the program that achieved the most progress in
designing a national system architecture. U.S. national institutions worked against centralization,
but the system architecture was the most centralized feature of any ITS program. This surprising
centralization was made possible by the governance structure in the transport sector. In the U.S.
transport sector a single agency, the FHWA, possessed national authority for oversight of road-
building and traffic. The FHWA could easily assume sole responsibility for the task of planning a
national system architecture. Even if that system architecture is not realized as envisioned by the
top-down engineering approach used up through 1995, the U.S. program is likely to have strong
national coherence thanks to the unity of the governance structure.

The unity in the U.S. program can be understood in four ways. Each sheds light on how
centralization could be achieved in the decentralized U.S. political system. First, the FHWA
exercised a centralizing influence in areas of the ITS program that were less subject to

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decentralizing effects of national institutions. Congressional earmarking, particularly in the early years of the program, typified the undesirable tendencies of national institutions. Yet this did not conflict with the FHWA's concern with a national system architecture. The FHWA could focus on a coherent system design, while Congress focused on program spending. The effects of national and sectoral institutions were felt in the different dimensions of spending and system design.

Second, the FHWA also exercised considerable influence over program funding. Many earmarks were vague enough to leave discretion with the FHWA. Some earmarks (e.g. to universities) consisted of a sum of money with little additional description; the recipients had to negotiate with the FHWA to define the content of the work to be performed. Other earmarks were more specific about projects, but the FHWA could still negotiate with recipients over technical details. Thus Congress' control of funding still left ample discretion to the FHWA to define how funds would be used.

Furthermore, all funding appropriated by Congress passed through the USDOT, particularly the FHWA. This gave additional financial leverage to the FHWA. Most ITS projects were funded between 80% and 100% by the federal government, and FHWA could object to proposals that it found incompatible with the national program. The FHWA gained a degree of power from this arrangement.

One example of a clear conflict between the FHWA and a state occurred around a large field test
in Michigan, called Fast-Trac. Michigan Congressman Robert Carr occupied an influential committee chair that allowed him to make multi-million-dollar earmarks for the test. The FHWA did not like the field test, because it used existing technology, rather than innovative technology, and because much of that technology came from overseas suppliers like Siemens. Yet the agency could not force Michigan transport officials to modify their plans because of their powerful benefactor in Congress. However, during the course of the ITS program Congressman Carr lost his committee chair position and with it the ability to earmark such large funds. From then on the FHWA ended the special considerations made for Fast-Trac. The power of the FHWA proved more enduring than the power of a Congressman, and over time the agency could assert central control over a state that had gone its own way. Thus, the agency's discretion over federal funds gave it considerable influence.

Third, the FHWA also used technical expertise as a source of influence over the program. The FHWA made clear from the outset that future federal support for ITS deployments would be contingent on those projects' conformity with the system architecture. The FHWA had long exercised responsibility for overall system design and standardization for U.S. highways, and this approach to overseeing the ITS system architecture was consistent with that. Although by 1994 the system architecture was not yet ready to be used as a lever to influence ITS deployments, it would clearly serve such a purpose.

This strategy of using technical expertise to counteract the distributive pork barrel tendencies of U.S. political institutions had a long and honored history in the road transport sector. Indeed the

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strategy is the focus of an entire book, Bruce Seely's *Building the American Highway System: Engineers as Policy Makers.*\textsuperscript{234} The FHWA's development of a national system architecture was another instance of this strategy.

Most of these features of FHWA strength are suggestive in character, rather than solid evidence of central power. With the exception of the conflict over the Michigan Fast-Trac field test, there were few instances of federal-state conflict by which to measure the relative strength of the different parties. However, a fourth aspect of the U.S. sectoral institutions in transport provided clear evidence of the *absence of weakness* in the FHWA, if not the presence of strength.

Only in the U.S. transport sector did the governance structure in transport not create conflicts in and of itself. In Japan rivalry between the Ministry of Construction and the National Police Agency predated the development of ITS. The divided governance structure made development more difficult, for the two ministries refused *a priori* to collaborate with each other. Even if ITS development did not in itself create conflicts, the fact that it required the collaboration of two rival ministries did. Similarly, in Europe the German Ministry of Transportation refused to even participate in ERTICO. With authority for transport divided among different national ministries, the German ministry did not want to take any action that might weaken its claim to authority over transport policy. Again, sectoral institutions in those countries were a source of state weakness. Only the U.S. was largely free from such turf battles at the national level; this *absence of disunity* was a source of central power in the program.

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Thus in a number of respects sectoral institutions affected ITS programs in a manner contrary to the effects of national institutions. First, national and sectoral institutions sometimes operated in different dimensions, leading to simultaneous centralization and decentralization. Second, the U.S. program's distributive spending was tempered by the FHWA's intermediary role as the central distributor of program funds. Third, the FHWA's long history of using technical expertise for central planning gave it additional leverage to resist pork barrel politics; the national system architecture not only manifested the FHWA's power, it was also a source of future leverage for the agency. Finally, the lack of bureaucratic rivalry in the U.S. transport sector eliminated a major source of counterproductive institutional forces that hampered programs in Europe and Japan. All these factors contributed to the influence of the FHWA, rendering it more powerful as a central bureaucracy than the literature on U.S. institutions might predict.

In summary, this study attempts to contribute to knowledge in a variety of areas. Its results contribute to literature in the systems, the rational actor, process, and institutional approaches.
Suggested Further Research

This study suggests some further topics of research. These are briefly listed here.

Further research could apply the sectoral institutions model to other case histories. In particular, the model could be investigated in fully private sector development programs. Although the ITS cases all involved public-private interaction, the model’s concepts should prove valid in purely public or purely private settings. Possible industry cases could be automated teller machines or computer data networks.

Additional research might identify additional sectoral institutions. The division of labor, governance structures, and frameworks for funding sufficed to explain the outcomes of the ITS programs. Attempts to develop the model further by investigating other development programs might reveal additional sectoral institutions. Such further elaboration might improve the utility of the model as a tool for practitioners; the greater the repertoire of structural features known to affect development, the better can practitioners analyze their context and plan strategies for development.

Another possible topic of research would be an investigation of the way that the structure of a technology affects its chances of political survival. ITS was a highly malleable vision that could adapt to many different coalition demands. Less malleable technologies may fare less well. For example, even as ITS won support, Congress declined to support magnetically levitated ("maglev") trains. The maglev technology may simply not have been malleable enough to
accommodate such a broad variety of interests. A historical examination of other technical visions and their success or failure in the political arena may show the relationship between technology and political viability.

Further research could also investigate whether state-level institutions might not provide a more hospitable environment for some U.S. commercial technology policies than federal institutions. With some states’ economies related to particular sectors, sectoral policies might be more politically viable at the state level than the federal level. For instance, following their policy failure at the national level, maglev proponents attempted to launch a development program at the state level in New York. With the maglev industry champion (Grumman) located in New York, the distributional implications of maglev were quite favorable at the state level. Furthermore, at the state level it became possible to propose an operational test well-matched to political interests. Proponents proposed a train track from New York City to Albany, presumably ensuring that many political jurisdictions would benefit from the program. ITS satisfied such distributional requirements at the national level; maglev could only hope to do as well at the state level.

Finally, further research could be done to further develop the practical implications of the model of sectoral institutions proposed here. This would refine methods that could be used by practitioners to analyze sectoral institutions and to build coalitions and make trade-offs in the development process. The goal would be a handbook of practical techniques.

All these further research topics would build on the work in this study. The topics would

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continue this work in a number of different directions.

The development of ITS throughout the world provided an opportunity to examine the interaction of large technical system development with social context. The existence of five parallel programs pursuing the same vision in different institutional contexts illuminated the influence of institutions on development. This study defined a set of sectoral institutions that shape development and explained the dynamics by which that shaping occurs. It is hoped that the product of this study will have some value for both theorists and practitioners.
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4. "Foreword" in Mayntz and Hughes, eds., *The Development of Large Technical Systems*. No attempt is made here to provide an exhaustive analytical definition of large technical systems. For such an attempt see: Joerges, Bernward, "Large Technical Systems: Concepts and Issues," in the same volume.

5. The development of system capabilities for the management of an existing network is hardly unprecedented. In the 1950s the air traffic control system increased the number of planes that could fly on a given air corridor and simultaneously reduced the danger of collisions. ITS would provide similar systemic functionality for road networks. See La Porte, Todd, "The United States Air Traffic System" in Mayntz and Hughes, eds., *The Development of Large Technical Systems*.


15. Programmatic success: Sapolsky; programmatic failure: Cohen and Noll, McNaugher; system design: Hughes; system accidents: Perrow; system optimization: de Neufville.

16. It is interesting to note that this literature on system development is not widely known among practicing system developers, nor is it taught in the engineering universities that train them. This situation probably reflects the institutional biases of a research university, most notably the criteria for faculty retention or termination. Faculty with highly focused expertise in the social sciences or engineering satisfy the criteria for retention. In contrast multi-disciplinary faculty studying large technical systems may tend to be eliminated due to their lack of specialization. Thus knowledge of heterogeneous systems may simply be unsustainable within a research university. This institutional bias in universities and the resulting lacunae in university curricula may contribute to the repeated problems in development documented by Cohen and Noll.


19. This term was widely used by developers in the U.S. program in ITS. It is also mentioned in McNaugher, *New Weapons, Old Politics*, p. 4.


21. Cohen and Noll, *The Technology Pork Barrel*, cite a number of such early cost-benefit analyses. For a related analysis, see Sapolsky's account of rational program management techniques (PERT) in *The Polaris System Development*.


32. Sapolsky, The Polaris System Development, Chapter 4, "PERT and the Myth of Managerial Effectiveness."


37. Hughes, Thomas, "Technological Momentum."

39. Perhaps the concept of heterogeneity is best suited for the classroom rather than the research program. As researchers in political science, sociology, engineering, etc. gain specific insights into systems, they can all be studied and integrated in one course of study. Of course, this presupposes teachers able to teach broadly, which runs contrary to the logic of a research university, as noted above.


51. A particularly sophisticated technique for recognizing institutions has been developed by Donald Schon and Christopher Argyris. Their method of inquiry constitutes a kind of organizational psychoanalysis in which patterns of behavior are examined and traced back to organizational structures. They propose techniques whereby organizations can "learn to learn," becoming expert in investigating the patterns of interaction that reveal institutional effects.


55. Logsdon, "The Space Shuttle Program: A Policy Failure?"


59. Both Hughes and Cohen and Noll make the same observation. See the literature review in Chapter 2.

60. Indeed, a "large technical system" and a "sector" refer to nearly the same thing. The U.S. transportation sector as it existed in 1991 was largely a reflection of the Interstate Highway System. ITS, if successful, promised to transform the sector into a reflection of that system. Sectoral institutions are the structure of the previous generation of large technical system, within which the next generation system develops.


63. Many writers on large technical systems, including Thomas Hughes and Linda Cohen, and Roger Noll, have identified stages in the development process. The definition and number of stages depends in part on the writer and in part on the technology itself. The stages defined here are a useful heuristic and are not meant as a strong claim by the author about development and its necessary trajectory. See Hughes, "The Development of Large Scale Systems" and


76. "Coordination among the different segments of the transportation system and control of transportation activities is an area in which Japan has had problems... [T]he separation of..."

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administrative functions regarding transportation among ministries has led to lack of coordination, especially concerning the important area of highway investment under Ministry of Construction control." Kinju, Naito, "Transportation Administration" in Kodansha Encyclopedia of Japan (Tokyo: Kodansha, 1983), p.99.


78. "... the bulk of local government funding comes through the central government, giving the latter an important lever over local activities... Police and educational functions, frequently the most important activities carried out by local governments in other countries, are under central direction in Japan." Pempel, T.J., Policy and Politics in Japan (Philadelphia: Temple University Press, 1982), pp.18-19.


82. "Where the size of a project is so large the number of potential optimal-scale efforts is very small (maybe only one), then it is a question of joint research or no research." Eads, George, and Nelson, Richard, "Japanese High Technology Policy: What Lessons for the U.S.?", in Japan's High Technology Industries (Seattle: University of Washington Press, 1986), p.253.


90. Takada, et al., "Road Automobile Communication System (RACS) and Its Economic Effect."


92. Nakashita et al., "Advanced Mobile Traffic and Information System (AMTICS)," p.4.

93. Nakashita et al., "Advanced Mobile Traffic and Information System (AMTICS)," p.3.


95. French, Robert, et al., *A Comparison of IVHS Progress in the United States, Japan and Europe Through 1993*, p. 55. Many overseas observers explained these high numbers by noting that navigation systems were frequently bundled with more desirable equipment like car stereos. Thus sales figures of ITS units do not represent a direct expression of consumer demand.


105. These numbers are taken from Fujita, Okihiko, "Social Effects of VICS -- Costs and Benefits."


108. *Bundesministerum fuer Verkehr (BMV).*

109. At that time called the *Bundesministerum fuer Forschung und Technik (BMFT).*


120. Interviews with Mr. Hans-Peter Glathe and Ms. Monika Kupke of Daimler-Benz.


122. *Position Paper: PROMETHEUS (Draft).*


125. The fourteen companies were Jaguar, Fiat, Peugeot, Alfa Romeo, Volvo, Renault, Porsche, Saab, BMW, Mercedes, Volkswagen, Rover, Matra, and Rolls Royce. (Saab and Volvo officially joined shortly after the EUREKA Conference.)


128. Prof. Dr. Legat, German Ministry of Traffic, 1987, Translation by U.S. Department of State, Division of Language Services, LS No. 126475, BL, German, p.6.


*Endnotes*


136. Interview.


140. Interview with Walter Scholl, p.3.


143. "DRIVE: RESULTS OF EXPLORATORY INVESTIGATIONS. SUMMARY" (Draft), prepared for DG-XII by MVA Systematica, July 1986, p. 3.


145. Karamitsos interview.

146. Glathe interview.

147. Karamitsos interview.

148. Karamitsos interview.


152. These observations were made by the Daimler-Benz representative on SECFO.


155. Treaty on European Union, Title XII, Trans-European Networks.

156. DRIVE '91, p. 9.

157. The terms "deployment" and "implementation" are used interchangeably here. Although ERTICO had the word "implementation" in its name, its activities are described here in terms of "deployment" in order to maintain consistency of terms across case histories.


159. Glathe interview.

160. Karamitsos interview.


162. DRIVE II funding was 124 million ECU (Inside IVHS, November 9, 1992), p. 6.

163. This incident was mentioned by several interviewees in DG-XIII in the summer of 1994.


166. DRIVE '93, Section 2, p.23.


170. PROMETHEUS Research Newsletter, Number 1, July 1988, pp.3-4.

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171. One member of SECFO claimed that fully 65% of DRIVE funding went to projects initiated by groups affiliated with PROMETHEUS. Tage Karlsson, *PROMETHEUS Research Newsletter*, No. 4, June 1989, p.3.

172. Glathe interview.


180. *Inside IVHS*, November 9, 1992, p.3.


188. Shladover et al., "California and the Roots of IVHS."


190. For the views of the FHWA Administrator in the Bush administration, see Larson, Thomas D., "IVHS: That Vision Thing," *IVHS Review*, Spring 1993, pp. 3-10.


192. USDOT is often characterized as a loose umbrella organization that joining together relatively independent agencies in it. These agencies include FHWA, the National Highway and Traffic Safety Administration, the Federal Transit Administration, and the Research and Special Programs Administration, all of whom began attending Mobility 2000 meetings.


196. Shladover et al., "California and the Roots of IVHS," touch on this dynamic, p. 32.


199. The premature announcement concerning ARTS was made at the IVHS Policy Workshop on Institutional and Environmental Issues held at the Asilomar Conference Center in Pacifica Grove, California, April 26-28, 1992.


201. Saxton, Lyle "Mobility 2000 and the Roots of IVHS."


203. A phrase widely quoted by former Mobility 2000 members. They did, however, regain significant control of the program.

*Endnotes*


210. Total funding from FY1991 to FY1995 was $787.3 million. Of this, 59.7% ($468.2) was for Operational Tests or Corridors. In turn, 78.2% of this ($366.3 million) was earmarked. USDOT, FHWA, Implementation of the National Intelligent Transportation Systems Program: A Report to Congress, 1995-95, Draft 10-26-95, p. 4.


221. That tradel journal was *Inside ITS*.

222. Secretary of Transportation Pena announced "Operation Timesaver" at the Annual Meeting of the Transportation Research Board in Washington, D.C., in January 1996. This was an adjustment to the national ITS program that emphasized proven technologies and staff training. Advanced technologies were deemphasized. "Operation Timesaver," *ITS America News*, January 1996, Vol. 6, No. 1, p. 1.


