U.S. Department
of Transportation

**Federal Railroad
Administration**

**Office of Research and Development
Washington, D.C. 20590**

An Industry Perspective on Maglev

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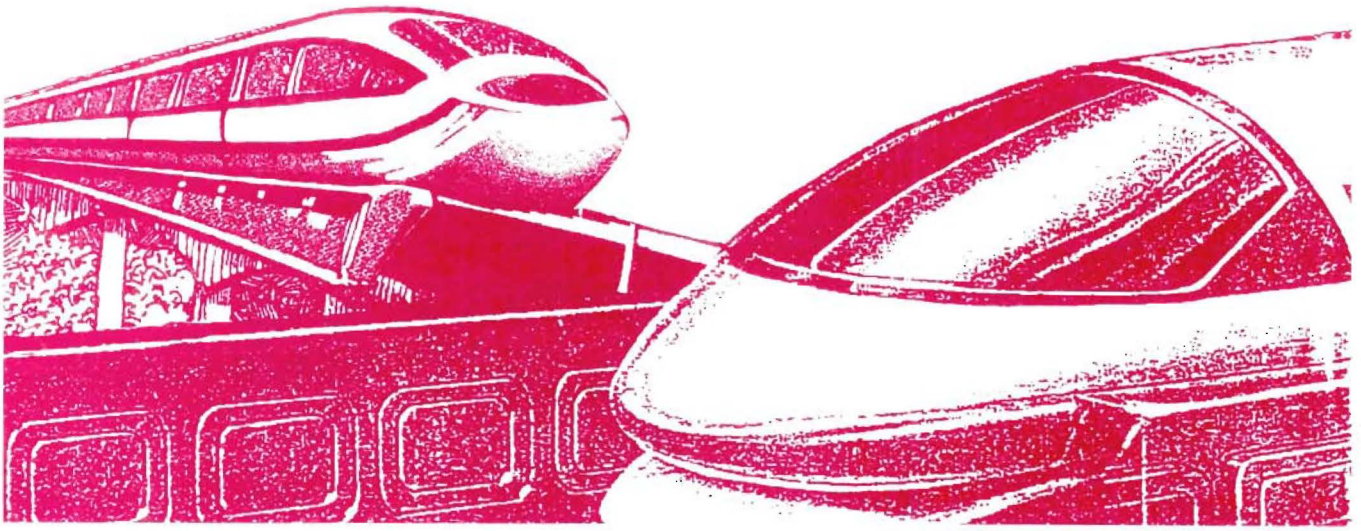

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Final Report

I. Executive Summary

Most of the recent discussion and proposed legislation concerning Maglev assumes that U.S. industry has a strong interest in Maglev and will be willing to take a pro-active, cost-sharing role in the development of Maglev systems.

As part of the preliminary feasibility studies on Maglev, the Federal Railroad Administration (FRA) obtained the perceptions of several major U.S. corporations and identified their interest in a Maglev program, their willingness to participate, and any potential barriers to their participation.

These industry perspectives were obtained through an independent and unbiased external study that included in-depth interviews with senior executives from 22 major U.S. corporations. These companies spanned a wide range of industries with skills relevant for Maglev development, including such differing interests as construction, steel, electronics, aerospace, defense, railroads, and automotive.

The study, conducted during April and May 1990, was primarily directed at the development and implementation of a next-generation "leapfrog" Maglev system in the United States. It was not aimed at assessing the interests of individual entrepreneurs in implementing existing German (or Japanese) systems.

The study found that the industry views are as follows:

- At present, there is a relatively low level of industry interest in Maglev.

- Most respondents see a critical need for a future high-speed ground transportation (HSGT) system in the United States. Maglev is perceived to be one of several technologies that could contribute to this total transportation system concept.

- U.S. industry clearly has the skills necessary to achieve leadership in Maglev technology, but the main issue is whether it should even attempt to do so. If it does decide to "leapfrog," it must build upon and improve the existing German/Japanese technology. It should not, however, aim to "re-invent the wheel." Instead, U.S. industry should focus its efforts on the guideway and associated construction technologies in order to cost-reduce the system for mass production.

- Although most of the companies interviewed would be willing to participate—to some extent—in a Maglev program, there is great reluctance toward considering any significant cost sharing. At present, funding of Maglev R&D is clearly seen as a federal government responsibility.

- Four major barriers presently preclude U.S. industry from taking a more pro-active interest in Maglev. These barriers suggest that there is:

  - No clearly visible market and profit opportunity in Maglev technology development — "The market is too far away and uncertain to warrant spending today's precious R&D resources."
  - No clear federal government commitment to a long-term national ground transportation policy
  - A genuine shortage of resources — "In today's competitive world we need all our available cash and people just to protect our existing core businesses."
  - A lack of public interest in mass transportation

In order to overcome these barriers, U.S. industry needs to see a substantial, long-term commitment by the federal government. The following major actions, in order of priority, were proposed:

1. Establish a clear definition of the future role and market for Maglev, with a high degree of commercial and technical realism

2. Provide major federal government funding for Maglev R&D. Initial industry contribution is unlikely to exceed 10 percent (too risky)

3. Develop a national high-speed ground transportation policy, which is supported by the public and state/local government

4. Provide legislative changes, where needed, to support Maglev R&D and implementation (e.g. in relation to right-of-way availability and patent recognition for U.S. industry's contribution)

5. Establish a "program champion" in the federal government and an appropriately structured government/industry management team

6. Develop compatibility standards for Maglev design and construction

7. If needed during initial implementation, provide capital, and right-of-way and/or operating cost subsidies

8. Undertake a detailed assessment of environmental and safety issues

In summary, the overall perspective indicates a high level of U.S. industry confidence in delivering Maglev technology, but a great deal of uncertainty and risk concerning the market for Maglev and the associated business opportunities. The federal government is clearly perceived to have a major role in bringing Maglev to a stage where it is a viable business opportunity that will warrant investment by U.S. industry.

II. Survey Structure

The Federal Railroad Administration commissioned the business and technology consulting firm of Arthur D. Little, Inc., to undertake the industry study. The following was involved as part of the participant selection process:

- Invitations to participate in the study were issued by the FRA Administrator...
- A total of 62 firms were invited to participate, of which 22 were interviewed and 40 declined...
- A structured set of six basic topics was used for each interview (varied slightly by sector of industry involved).

A. Invitations

To ensure maximum response to the survey, personal invitations to participate (*Appendix A*) were issued by the FRA Administrator to the chief executive officers of the selected companies. Where the companies were divisionalized or conglomerates, the parent or holding company was addressed.

All companies were subsequently contacted by telephone to establish either an agreement to an interview or to obtain a firm refusal to the opportunity.

B. Respondents

A total of 62 companies were invited to participate, based on a "semi-structured" sample approach, with the requirement that:

- All companies are large enough to make a significant, potential contribution to Maglev (present sales over $2 billion, annually)
- All companies have the skills or knowledge relevant to either Maglev R&D or implementation/operation
- Beyond the above criteria, no attempt was made to pre-select participants

Forty companies either expressed little interest in an interview or gave firm refusals. These companies are listed in *Appendix B*.

The statistic (40 rejections out of 62) does not necessarily imply a lack of industry interest, but is more a reflection of the semi-structured sample used in the original contacts.

The 22 companies that agreed to participate in interviews provide a good cross-section of the various industries that could contribute towards Maglev development (*Figure 1*).

Figure 1. Companies Interviewed

Construction/Steel

- Bechtel
- De Leuw Cather
- Morrison Knudsen
- Parsons Brinckerhoff
- U.S. Steel

Automotive

- Ford
- General Motors (Including Locomotive Div.)

Electronics/Computers

- Asea Brown Boveri
- AEG Westinghouse
- Allied-Signal
- Digital Equipment

Railroad/Locomotive

- GE Transportation
- Santa Fe
- Union Pacific

Aerospace/Defense

- General Dynamics
- Grumman
- Litton Industries
- Lockheed
- Raytheon
- Rockwell International
- United Technologies

Investment Banks

- Goldman, Sachs

In order to obtain an authoritative opinion—representative of company position—interviews were arranged with senior executives. In most cases, the interviews were conducted with a corporate vice-president, or above (*Figure 2*). A full list of interview participants is given in *Appendix C*.

C. Interview Process

Interviews were led by the external "product innovation" consultant, with a "transportation planning consultant" and a senior manager of the FRA present at most interviews. The FRA role was solely to monitor and clarify issues concerning the present status of Maglev in the federal government and was restricted from providing any potential bias to the responses.

Interview duration was typically 1 1/2 - 2 hours, during which the following structured set of six basic questions was explored:

- What Maglev activities are you currently engaged in? Are you considering any short-term or long-term planning for Maglev?

Figure 2. Positions of Interviewees

CEO/ General manager	Corporate vice president	Director/Other senior executive
• De Leuw Cather	• AEG Westinghouse	• Digital Equipment
• GE Transportation	• Allied-Signal	• Ford
• General Motors	• Asea Brown Boveri	• Grumman
• Morrison Knudsen	• Bechtel	• Union Pacific
• Parsons Brinckerhoff	• General Dynamics	• United Technologies
	• Goldman, Sachs	
	• Litton Industries	
	• Lockheed	
	• Raytheon	
	• Rockwell International	
	• Santa Fe	
	• U.S. Steel	

Note: Most interviews involved several personnel. The list above reflects the most senior person attending.

- What is Maglev's role in U.S. transportation?
- How can U.S. industry establish technology leadership and/or global competition in Maglev?
- In what way would you like to be involved in Maglev in the early development stages? During implementation?
- What barriers/constraints exist that would restrain your participation in a Maglev program?
- What actions could the federal government, or anyone, take to overcome these barriers/constraints?

To encourage candid replies, confidentiality of individual responses was ensured. In addition, each company is to receive a copy of this report, in recognition of its contribution.

Detailed findings from each of the six questions are contained in the following section.

III. Detailed Findings

A. Present Maglev Activities and Interests

Of the 22 respondents, five companies had been involved in prior U.S. Maglev R&D studies during the 1970s (*Figure 3*). Each of these companies ceased its Maglev activities after federal government interest and funding stopped; none has yet restarted, or presently intends to.

Figure 3. Prior Maglev Activities

Company	Area of R&D activity
• Allied-Signal	• Attractive/repulsive levitation, Linear Induction Motors (LIMs), power supply and distribution
• Ford	• Electrodynamic levitation concept
• GE Transportation	• Linear induction motors
• General Motors	• Electrodynamic levitation concept and vehicle damping
• Raytheon	• Co-sponsored MIT Magneplane and designed magnets, power systems

None of the 22 respondents presently has any R&D activities in Maglev, although five have some limited, proactive involvement (*Figure 4*).

All of the companies interviewed have been monitoring recent Maglev activities and publicity with a view toward assessing potential new business opportunities.

It was notable that potential users or operators of Maglev systems have not yet grasped a major interest. For example:

- None of the six airline operators or three express freight service companies that were contacted wished to participate in the interview program.
- Two railroad operators did participate, but one quoted, "Maglev is not yet a high-level conversation topic among railroad companies."

Figure 4. Present Proactive Involvement in Maglev

Company	Nature of involvement
• Asea Brown Boveri	• No U.S. activities, but European parent has done some work with Transrapid International in Germany
• AEG Westinghouse	• Presently involved in low-speed mass transit applications of Maglev • Member of Maglev, Inc., Pittsburgh, Penn. • German parent has worked with Transrapid International.
• Bechtel	• Strong interest in implementation. Teamed with Transrapid for Las Vegas, Nev.,/ Anaheim, Calif., proposal
• Grumman	• Have conducted numerous analytical studies over last two years
• U.S. Steel	• Member of Maglev, Inc., Pittsburgh, Penn., but not a major protagonist of Maglev

B. Role of Maglev in U.S. Transportation

All 22 respondents perceived a major need for an improved ground transportation system in the United States in order to reduce the localized transportation problems of gridlock and winglock that presently occur. In addition:

- Many potential benefits of Maglev were mentioned, *but* . . .
- Many disadvantages were also quoted.
- None are yet convinced that Maglev is the total or major answer.

The most frequently mentioned roles for Maglev were to replace short-haul aircraft in the near term and to replace railroads (including commuter rail and some freight) in the longer term.

Specific applications mentioned for Maglev were:

- Generally, 200-500 mile range and principally over 200 mph
- Airport-to-airport

- Airport-to-downtown
- City-to-city (for high-density corridors)
- Limited freight use (high-speed deliveries, perishables)

Numerous Maglev benefits were mentioned:

- Lower atmospheric pollution (versus aircraft and automobiles)
- Reduced oil import dependence (versus aircraft and automobiles)
- Fast and quiet operation
- Potentially lower maintenance costs versus high-speed rail; acknowledging that this is not yet proven
- May provide added economic development in United States
- Improved quality of travel (more space comfort versus plane)
- More exciting and "fun-to-ride" than passenger train
- Eliminates highway rail-grade-crossing safety problems

In spite of these perceived benefits, numerous disadvantages were seen, primarily:

- Public acceptance and economic viability (the major concerns)
- Unknown safety, reliability, and maintenance costs
- "Maglev does not address the weakest link in the transport system (urban traffic jams)."

Of the 22 respondents, all believe that a high-quality, total transportation system study is needed to define the market needs; revenues; profitability; and environmental, technical, and legal issues. Virtually, all of the 22 respondents stated that the market needs and total transportation system design should be the top priorities, as testified below:

- "Maglev appears to be a technology looking for a home."
- "First define the market needs, then select the technologies which satisfy them most economically."
- "It is no use having a 300-mph Maglev link when it takes two hours to drive to the Maglev station (in Los Angeles)."

C. United States Technology Leadership in Maglev

Most respondents believe the United States could achieve technology leadership in Maglev, since it has all the needed technological skills. However, the more important, initial question is, "Should the United States even attempt to achieve leadership?"

Of the 22 companies interviewed, only one is presently a proponent of the United States attempting to "leapfrog" in Maglev technology. All of the other companies stated that a detailed market/economic assessment must be conducted before deciding on the issue.

Assuming that the answer to this assessment is favorable toward proceeding with Maglev development, several suggestions for the technology development were made:

- **"A well-structured industry/government management team is clearly the correct approach."**

Number of companies who:	Agree	Disagree	Don't know/ No response	Total
	20	1	1	22

- **"Don't try to reinvent the wheel. Improve on the existing German/Japanese experience."**

Number of companies who:	Agree	Disagree	Don't know/ No response	Total
	17	0	5	22

- **"Team with the Germans or Japanese, or license their technology and improve it."**

Number of companies who:	Agree	Disagree	Don't know/ No response	Total
	14	2	6	22

Most companies (14) were unable to comment authoritatively on the relative merits of the Japanese (repulsive) system versus the German (attractive) system. The eight companies that did comment, all favored the repulsive (electrodynamic) system and considered that this should be the basis for any attempted U.S. "leapfrog" effort.

The main reasons given for favoring the repulsive (electrodynamic) system were:

- Potentially, there is much lower guideway construction cost.
  - Future developments may enable simple metal beam guideway without propulsion/levitation coils.
  - Tolerance requirements are much lower (repulsive system "self-stabilizes") resulting in less-costly substructure.
- It is safer due to lower tolerances. A bigger gap exists between the vehicle and guideway; therefore, there is less risk of impact. The repulsive system also needs wheels at low speed that provide for a "safe landing" in the event of a power failure. (The "safe hover" concept has not been proven yet.)
- It is lighter in vehicle weight and, therefore, is more energy efficient.

These eight companies all believed that guideway cost reduction is the major "breakthrough" needed in technology in order to make Maglev cost competitive and to provide U.S. technology leadership.

D. Interest in Participation in a U.S. Maglev Program

1. Participation in R&D phase

Although all 22 companies that were interviewed volunteered to be "good corporate citizens" and support a national Maglev initiative to some extent, the interest in committed R&D participation was mixed.

Not surprisingly, those companies who see the potential business opportunity are the same ones that seem most interested to participate. These are, primarily, the construction engineering companies and two other companies with present Maglev activities.

In spite of a strong or moderate interest in Maglev R&D participation, the overall reaction to cost sharing in R&D was negative, primarily due to the lack of perceived return on investment, at present (*Figure 5*).

2. Participation in implementation

Most companies found it difficult to assess their potential role in Maglev implementation. It is simply "too far down the road."

Very preliminary, potential implementation roles mentioned are listed in *Figure 6*. Willingness to make major equity participation (at this time) is noticeably lacking.

Figure 5. Companies That Would Consider R&D Cost Sharing

Number of companies who would presently consider a small (10 percent) contribution to Maglev R&D cost sharing (with government contribution of 90 percent).

Would consider	Might consider	Would not consider	Total
1	3	18	22

Figure 6. Potential Roles for Maglev Implementation

Role	Number of companies
• System design/construction management	7
• Subsystem/component/material supplier	14
• Equity interest in ROW	2
• System operation/maintenance	2
• Uncertain at this time	2

Note: Total exceeds 22; some companies responded positively to more than one role.

E. Barriers to Industry Participation

There were four major barriers to U.S. industry participation discovered in the survey. Each of the following was mentioned by most or all of the companies interviewed:

- The lack of public interest in mass transportation
- No clear federal government policy and commitment
- No defined market and business opportunity
- The lack of resources (cash/people) for high risk, peripheral new businesses

The lack of perceived public interest in mass ground transportation is a root cause of the barriers. For example:

- American culture is perceived to be "pro-automobile" and "anti-train."
- Public acceptance of passenger rail has been generally poor.

- Automobiles offer greater flexibility, lower cost, and better convenience for most of the United States' short- and medium-distance trips (up to 150 miles). Aircraft offer equal benefits in the 150+ mile range.

- The federal government has done little to educate the public to the benefits of existing rail transportation.

As a result of low public interest, no federal government policy has yet been developed for mass ground transportation. In addition:

- No complete "transportation network" philosophy has been developed, since the Interstate Highway Program.

- No role for either high-speed rail or Maglev has yet been defined.

Due to the lack of both public interest and federal government policy, industry can see no major market and business opportunity in Maglev. As a result:

- Isolated Maglev applications will be promoted, using existing foreign technology, when a business opportunity can be anticipated, *but* . . .

- There is no incentive for U.S. industry to develop any new "leapfrog" technology. One company quoted, "We estimate our business in Maglev propulsion system supply at around $200 million/year, 20 years away. Discounted to today's money value, it doesn't justify much investment in R&D."

Finally, many companies mentioned the lack of both financial and human resources, indicating that:

- Business pressures and the U.S. economic environment have resulted in high debt levels.

- Staff levels have been cut, and those remaining are needed "essentials" for existing core businesses.

- "In today's competitive environment we need all our valuable resources simply to protect existing businesses."

- "Today is a much tougher business environment than when we were developing Maglev in the 1970s."

F. Action Needed by the Federal Government

The unanimous opinion of the study participants was that, before U.S. industry can get excited about participating in new "leapfrog" Maglev technology development and

implementation, it must see a major long-term commitment by the federal government (as in the National Aerospace Plane 20-year-plan).

The survey confirmed three primary actions were needed to be undertaken by the federal government (*Figure 7*). They included:

- A clear definition of the Maglev market and business opportunity
- A complete or majority (90 percent or more) federal government funding of initial Maglev R&D efforts through a demonstration phase
- The formulation of a national policy for ground transportation

1. Maglev market definition

All of the 22 companies that were interviewed, except one, expressed major concern over the potential market for Maglev. They stressed that:

- Public acceptance is unclear.
- Feasible routes have not yet been defined.
- Operating costs and revenues are not known (convincingly).
- Construction costs are not known (convincingly).
- Technical feasibility, safety, and environmental questions are still open.
- It is not certain that Maglev is the right technology for the market need.

As a result of the—as yet—unknown market, technology, and introduction timing, the business opportunity for individual participants cannot be assessed satisfactorily.

2. R&D funding

Only four companies might consider a limited (about 10 percent) cost-sharing approach to Maglev R&D at present.

The remaining 18 companies either stated they would require 100 percent federal government funding or expressed little interest in participation in "contract R&D" at the present time.

The rationale for their decisions was uniform:

- No clear market and business opportunity
- Excessive risk
- Revenue stream too far in the future
- Available resources needed for other pressing priorities

3. National policy for ground transportation

Several essential precursors to Maglev market definition are seen to exist:

- To define the "next generation," total U.S. ground transportation system

- To clearly establish the role of Maglev
- To obtain public and state support of Maglev and the total transportation system
- To provide the coordinated leadership needed for Maglev development and implementation

The survey also identified a number of secondary actions needed *(Figure 7)*, such as:

- Legislative changes

Figure 7. Actions Needed by the Federal Government

Action needed	No. of companies who mentioned (unprompted) as an important action (maximum 22)
Primary	
• Clear definition of Maglev market and business opportunity	21
• Complete or majority (90%+) federal government funding of initial Maglev R&D efforts	20
• Formulation of a national policy for ground transportation	19
Secondary	
• Legislative changes to ease Maglev development/implementation	9
• Strong Maglev "program champion" in the federal government	7
• Definition of design and construction compatibility standards	6
• Funding/subsidy of implementation and operation	6
• Assessment of environmental and safety issues associated with Maglev	4

- A Maglev "program champion"
- Definition of compatibility (future network) standards
- Implementation/operating subsidies
- Assessment of environmental issues

a. **Legislative changes** - Nine companies mentioned the need for potential legislative changes to assist both Maglev R&D and implementation. The specific actions mentioned were:

   - Easing of federal government procurement policies to speed-up R&D contracting
   - Greater patent protection for participating industries. In particular, a longer protection period since Maglev introduction is 15 to 20 years away
   - Improved R&D tax incentives for companies who demonstrate "productive teaming" or switching of fields to be covered by R&D
   - Faster depreciation for guideways (20 to 30 years is too long)
   - Major need to collaborate with states and gain access to rights-of-way. This could be a "show-stopper"
   - Need to clarify ownership of guideways and role of private funding in a public service

b. **Program champion** - Seven companies mentioned the need for a strong "program champion" in the federal government who would drive the Maglev initiative. The Department of Transportation was suggested as the logical choice by some companies.

   There were no specific views on which department should have this role, but a clear definition of responsibility is considered important (i.e. not a "committee").

c. **Standards** - Six companies mentioned the need for compatibility or interface in design and construction standards. These should cover the basics, such as:

   - Guideway configuration and general construction type
   - Some capability for guideways to adapt to (electrodynamic) repulsive systems from the attractive (electromagnetic), which is judged to be the interim system
   - Compatibility of guideways between states

d. **Implementation subsidies** - Six companies considered that implementation subsidies would be needed, indicating that:

   - The farebox is unlikely to recover all capital costs.

- Other modes of transportation are also subsidized (highway, passenger rail, air); there is a need for a level playing field.

- The provision of mostly free rights-of-way could be one subsidy mechanism.

e. **Environmental issues assessment** - Current investigations of Maglev magnetic field emissions and potential health effects, and Maglev safety are considered fundamental. The federal government has the responsibility for setting the requirements in these areas. Magnetic fields, in particular, could be a "show-stopper."

   Noise levels should also be assessed and compared to other transportation modes.

APPENDIX A

U.S. Department
of Transportation
**Federal Railroad
Administration**

Office of the
Administrator

400 Seventh Street, S.W.
Washington, D.C. 20590

February 16, 1990

Dear

President Bush has requested that Congress fund research and development to stimulate American participation in the evolving technology of magnetically levitated (maglev) transportation, a new concept in which magnetic forces support vehicles above a guideway providing a contact-free system with cruise speeds above 300 miles per hour. The future health of the American economy is tied to a safe and efficient transportation system. Maglev technology offers a means to address our nation's future transportation demands and, at the same time, serve as a stimulus for U.S.-based technology and manufacturing. Background material on maglev is enclosed for your information.

Although early research and development on maglev was conducted in the U.S., the current leaders are the West Germans and the Japanese. Currently, both countries are testing full-scale passenger-carrying maglev prototype systems. Some believe, however, that neither system has reached the level of efficiency and reliability necessary for commercial application in the U.S. and that further development is needed. In cooperation with industry, the Federal Railroad Administration and the U.S. Army Corps of Engineers will assess the extent that this is true and whether the U.S. should develop advanced maglev technology.

The input of American industry, which would ultimately design and manufacture U.S.-based maglev systems, is a vital part of any realistic analysis of this issue, and we welcome your views. We look forward to a brief meeting with you and your staff to discuss issues key to the development of maglev technology.

Thank you for your assistance on this very important issue.

Sincerely,

Gilbert E. Carmichael
Administrator

Enclosure

APPENDIX B

Companies Which Declined Maglev Interviews

American Airlines, Inc.
AMP Inc.
ARMCO, Inc.
Ashland Oil Inc.
AT&T Technologies, Inc.
Bethlehem Steel Corporation
The Boeing Corporation
Chrysler Corporation
Control Data Corporation
CRS Sirrine, Inc.
CSX Corporation
Delta Air Lines, Inc.
Emerson Electric Corp.
Federal Express Corporation
GTE Corporation
Harris Corporation
Hewlett Packard Co.
Honeywell Inc.
Inland Steel Industries, Inc.
International Business Machines
ITT Corporation
Johnson Control Inc.
LTV Corporation
Martin Marietta Corporation
McDonnell Douglas Corp.
Motorola Inc.
Northrop Corp.
North American Phillips Corp.
Northwest Airlines, Inc.
Schlumberger Ltd
Teledyne, Inc.
Texas Air Corp
Texas Instruments, Inc.
Textron, Inc.
Trump Shuttle
TRW Inc.
Unisys Corporation
United Air Lines
United Parcel Service
U.S. Air

APPENDIX C

Companies and Persons Interviewed

Company	Interviewees	Position
Asea Brown Boveri	Jack T. Sanderson	VP, Corporate Technology
	Hans Rudolf Zeller	Asst. VP, Mgr of Department Materials Science
	Roger Eblovi	Sales Manager
AEG Westinghouse Transportation Systems, Inc.	Donald R. Marcucci	VP, Commercial Operations
	Jeffrey A. Stayer	Mgr, Commercial Services
Allied-Signal Aerospace Co	James E. Strang	VP, Technology
	Charles H. Weinstein	Product Line Mgr., Electrical and Power Systems
	Gabor Kalman	Research Scientist
The Atchison, Topeka & Santa Fe Railway Co.	C. R. Kaelin	Asst. VP, Staff Services
	Mark P. Stehly	Gen. Dir., Technical Services Off. of VP - Operations
	R. Mark Schmidt	Dir., Operations Research
	N. C. Marsh	Director, Dept of Technical Research & Development

The Atchison, Topeka & Sante Fe Railway Co.	Geoffrey E. Dahlman	Mgr., Research & Tests Dept of Technical R&D
Bechtel	Ervon R. Koenig	VP, Bechtel International
	Melvin Mirsky, P.E.	Mgr., Surface Transportation
DeLeuw Cather	David S. Gedney	President & Chairman of the Board
	Gary E. Griggs, P.E.	Senior Vice President
	Robert S. O'Neil	Senior Vice President
Digital Equipment Corporation	Rita M. Yavinsky	Civilian Agencies, Industry Marketing Manager
	Michael A. Aisenberg	Mgr., Fed. Govt. Relations
	Rubin S. Olsher	Mgr., Fed. Accts - Advanced Research Agencies
	Jack Demember	Mgr., Technology Transfer
Ford Motor Co.	J. R. Wallace	Dir., Elect.Sys.Res.Lab Res. Staff
	L. Craig Davis	Prin. Res. Sci. Physics Dept.
General Electric Company (Transportation Div.)	Michael D. Lockhart	Vice President
	Michael W. D. Howell	General Manager
	Larry W. Ishler	Mgr., Electronic Systems

General Electric Company	Alex W. Hudak	Mgr., Transit Marketing & Sales
General Dynamics Corp	J. Clifford Schoep	Corporate Director, Research and Advanced Develop.
General Motors Corp.	William E. Hoglund	Executive Vice President
	George C. Eads	Vice President & Chief Economist
	John S. Gable	Gen. Dir. of Business Units
	Linos J. Jacovides, Ph.D.	Head, Electrical & Electronics Engineering Department
	Stephen E. O'Toole	Sr. Washington Rep. Ind. Govt. Relations
Goldman, Sachs & Co.	Michael R. Armellino	Partner
	Mark R. Tercek	Vice President, Invest. Banking Division
Grumman Corporation	Richard J. Gran, Ph. D.	Director, Advanced Concepts Corp. Technology
	Michael Proise	Technology Advisor, Advanced Concepts
Litton Industries, Inc.	Charles S. Bridge	Vice President - Chief Scientist
	Dr. Jonathan K. Scudder	Corporate Staff Scientist
Lockheed Corporation	Dr. R. P. Caren	Vice President, Science & Engineering
Morrison Knudsen Corp	James N. Ellis, P.E.	President, Transportation &

		Water Resources Group
Parsons Brinckerhoff, Inc.	James L. Lammie	President & Chief Executive Officer
	William H. Lathrop, P.E.	Senior Vice President
	Tom S. Taylor, PE	Vice President, Princ. Prof. Asso.
	R. K. Pattison	Technical Director - Railroads
Raytheon Company	Elliot Ring	Director, Engineering
	Edmund B. Woollen	Director, Govt. Group Marketing
Rockwell International	R. F. Stehle	Vice President, Bus. Develop.
	Donald I. Carter	Director, Aerospace & Electronics Technologies
	Roger E. DeWames	Distinguished Fellow
Union Pacific Railroad	Donald W. Bolt	General Director, Research & Equipment Requirements, Field Operatoins
United Technologies Research Center	Frank R. Biancardi	Manager of Advanced Systems Technology
U.S. Steel	Keith K. Kappmeyer	Vice President, Engineering & Research