Biannual Report

Covering the Period August 15, 1974 through December 31, 1976

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TECHNOLOGY TRANSFER — TRANSPORTATION

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Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
TECHNOLOGY UTILIZATION OFFICE
AMES RESEARCH CENTER
MOFFETT FIELD, CA. 94025

Attention: Mr. Charles C. Kubokawa

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SRI Project PYU-3670

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EXECUTIVE SUMMARY

Introduction

Much of the wealth of scientific and technological information developed under the sponsorship of the National Aeronautics and Space Administration has proved useful and beneficial for mankind when applied to nonspace problems. To expedite this broad utilization of advanced technology, NASA initiated its Technology Utilization Program with the overall objectives of transferring aerospace-derived technology for the solution of important technological problems in the areas of public transportation, housing, environment, and biomedicine. To assist NASA in achieving this transfer of knowledge, key research organizations throughout the country have established Technology Application Teams. These teams work actively in specified areas of public concern, helping to match problem and solution, and following through to ensure the most efficient utilization of the transferred technology.

The SRI Technology Applications Team is primarily concerned with problems of the transportation industry. Members of the team routinely work with a user community* comprising representatives of the Department of Transportation, the railroad and rapid transit industry, and state highway departments, to name a few. In addition, team members maintain active contact with NASA's scientific community and continually strive to bridge the gap between key technological needs of the user and the available technology or expertise at NASA. This report presents in detail the activities carried out during 15 August 1974 through 31 December 1976.

Highway Problems

Highway-related needs for which the SRI team identified applicable

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* Appendix A contains a list of user agencies benefitting from SRI Team Activities.

NASA-derived technology included: the need for a longer lasting corrosion-resistant coating, solved by applying a zinc-rich coating developed at Goddard Space Flight Center; the need for inexpensive skid testing equipment, solved by the Langley Diagonal-Braked Vehicle; the need for a more effective highway crash barrier, solved by application of lunar lander impact attenuation technology; and the need for pavement marking more clearly visible on rainy nights, solved by modification of chemiluminescent formulations developed at Goddard Space Flight Center. Other developments related to highway needs included a new bridge-icing alert system, a new soil moisture analysis technique, and an improved brake friction material.

Railroad and Rapid Transit Problems

Rail industry needs addressed by the team included: the need for early warning of roller bearing failure to prevent derailments, solved by application of an acoustic signature technique developed under funding from Marshall Space Flight Center; the need for detection of residual stresses in wheels and rails to warn of imminent failure, solved in part by a nondestructive evaluation (NDE) technique developed at Marshall; the railroad's need to understand the dynamic relationships between railcar and track, helped by track/train dynamics research sponsored by the Federal Railroad Administration and performed by Marshall Space Flight Center and its contractors; and the anticipated need for quieting locomotives, possibly solved by application of noise suppression technology developed at NASA's Langley Research Center.

In addition, the need of the rail industry for more fire-resistant construction materials and that of the rapid transit industry for management techniques designed for systematically handling major problems of high complexity are being addressed by NASA scientists at Ames, Johnson, Lewis and Kennedy Space Centers.

Waterways and Other Problem Areas

Other problem areas addressed by the SRI Team included those of waterways operators such as the U.S. Coast Guard and the U.S. Maritime Administration, those of the trucking industry and the recreational vehicle industry, and transportation-related problems of the law enforcement community. Many of the projects started in these areas have not yet reached the transfer stage.

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I INTRODUCTION

The technological advances achieved by the National Aeronautics and Space Administration as it fulfills its mission of exploring space have proved highly useful when applied to many earthbound problems. Advances in techniques relating to biomedicine, environment, transportation, and housing have been applied to public sector problems through the efforts of NASA's Technology Utilization Office. It is the mission and goal of this office to derive the most beneficial utilization of all advanced technologies developed under NASA auspices.

The transfer of technology usually does not occur spontaneously. The diffusion of new information is a slow process and if not handled in a capable manner it may never occur. To assist the Technology Utilization Office in transferring technology in the most expeditious manner, and to ensure its proper utilization, a number of key research organizations within the United States have established Technology Applications Teams. These teams, working closely with NASA research scientists and technology utilization specialists, identify solutions derived from NASA technology. It has long been shown that the active approach to this transfer of technology, or active problem/solution matching, as embodied by the team concept is the most effective tool for the dissemination and promulgation of advanced concepts and devices.

SRI has established such a Technology Applications Team with transportation as its main area of concern. Members of the SRI team during this report period were: Dr. Tom Anyos, Director, Mr. Ian M. Brown, Ms. Ruth M. Lizak, Mr. Andrew V. Loomis, and Mr. James P. Wilhelm.

Consultation and technical assistance was available to the core team from Mr. Neville H. G. Daniels, Sr. Research Engineer and Sr. Metallurgist, and Mr. Clark Henderson, Sr. Staff Scientist, Transportation. In addition, the core team can draw on the extensive and varied competence of SRI's staff for solutions or commentary on specified technical problems. This ability has allowed the team to match widely varying areas of NASA-derived technology to areas of public concern outside the team's direct expertise.

In its effort to seek solutions to problems in the area of public transportation, the SRI team has developed a number of techniques and methodologies for decreasing the time gap between the development of a new technology and its commercial availability. Thus, the team has been able to influence positively the movement of newly developed technologies across industrial, interdisciplinary, and regional boundaries. Highlights of this work are reported here.

II HIGHWAY PROBLEMS

A NEW CORROSION-RESISTANT PAINT

Because of their exposure to salt spray, coastal bridges require more corrosion protection than is needed inland. Currently available coatings provide protection for about 20 years on inland bridges, but less than 10 years of protection on bridges near the coast. In a study conducted by California highway engineers, a 25-year life inland was found to equal only 4-6 years on the coast.[1]

Bridge painting is an expensive procedure, mainly because of high labor costs. Painting of the Golden Gate Bridge in San Francisco, California, for example, requires 42 painters working for 5 years at $11.65 per hour. If coating life were doubled, savings of about $3 million could be realized for labor alone.

Zinc-rich coatings are known to provide excellent corrosion protection, and coatings using both organic and inorganic binders have been tested for bridge application. The inorganic-binder-based coatings have two advantages: They do not require a finish coat, and they give longer protection. It has been well established in tests conducted by NASA's Kennedy Space Center [2] and by Florida's Department of Transportation [3] that organic coatings cannot compete with inorganics in a coastal environment for abrasion resistance, chemical resistance, or effectiveness in a wide temperature range; moreover, they must be given a topcoat. Inorganic coatings differ from organic and galvanized coatings in two ways: (1) the inorganic system is chemically reactive, forming a chemical bond with the steel, and (2) the zinc silicate matrix, which completely surrounds each zinc particle with an insoluble and chemically resistant film, is conductive, so that the zinc cathodically protects any break in the underlying steel surface. Thus, the coating has a self-healing quality.

One disadvantage of the inorganic coatings is that they are harder to apply than organics. This problem appears to have been overcome by the potassium silicate zinc-dust-based coating developed at NASA's Goddard Space Flight Center. Potassium silicate is known to be an effective binder for zinc dust, provided the mole ratios of silica to potassium oxide are maintained at a high level. The mole ratios of currently available zinc-rich coatings generally peak at about 3.1:1; however, because of its unique binder formulation, the NASA coating has a range of 4.8:1 to 5.3:1.

The NASA coating contains 19 to 25 parts (percent solids in solution) by weight of potassium silicate, plus zinc dust (at 6 to 27 times the percent by weight of silicate solids). Table I shows the coating formulations for two different weight ratios. To this basic mixture, methyltrimethoxysilane is added in amounts up to 3% by weight to act as a buffer and to provide better adherence to steel. The silane also facilitates mixing with the zinc. After mixing is complete, most zinc-rich coatings must be strained to remove lumps of zinc; however, NASA's coating requires no straining because the zinc is dispersed completely. Its pot life is in excess of 48 hours, perhaps as much as 100 hours. This permits use of any coating that was mixed the previous day, or even several days before if, for example, application has been interrupted by rain. Currently available products have a pot life of 4 to 48 hours. Frequent mixing of small batches wastes labor and money.

The coating has a water base and is nontoxic, nonflammable, and self-curing. It is applied at a dry film thickness of 2-3 mils. One gallon is reported to cover 375 square feet, whereas the usual coverage for inorganics is about 200 square feet per gallon. Because it was developed for the space program, the coating was designed to resist (1) corrosion from salt spray and fog, (2) heat and fire from the rocket exhaust, and (3) the thermal shock created by rapid temperature changes.

Table I
NASA's ZINC-RICH PAINT
Coating Formulations

Formulations for weight ratio 3.06 (4.8 mole)

Ingredient	Parts by Weight	Ingredients	Parts by Weight
PS-7	2000	KASIL 6	1804
Silicic acid + Water slurry	257 320	Silicic acid + Water slurry	257 320
Water	1096	Water	1292
Methyltri- methoxysilane	70 (4% by weight of silicate as max.)	Methyltri- methoxysilane	70

Formulations for weight ratio of 3.38 (5.3 mole)

Ingredient	Parts by Weight	Ingredients	Parts by Weight
PS-7	2000	KASIL 6	1804
Silicic acid + Water slurry	355 434	Silicic acid + Water slurry	355 434
Water	982	Water	1178
Methyltri- methoxysilane	70	Methyltri- methoxysilane	70

Note: The Silicic acid used here was calculated on a basis of 84.5% silica content. The PS-7 has a 35% solids content and 2:1 weight ratio. The Kasil 6 has a 38.3% solids content and a 2:1 weight ratio.

Laboratory testing included a salt-spray test at the California Department of Transportation Testing Laboratory. Three panels coated with the zinc-dust-based formulations alone gave excellent performances, with no rusting or blistering after 5300 hours in the salt spray chamber. A panel topcoated with vinyl acetate (with vinyl phenolic tiecoat) also withstood a 5300-hour test with no sign of corrosion. California engineers consider a coating superior if it endures a 3000-hour test (3% brine); the paint industry places its test requirement as high as 4000 hours.

In April 1975, the potassium silicate zinc-dust coating was applied to a test section under the Golden Gate Bridge. As recommended, 16 pounds of zinc-dust were combined with 0.7 gallons of binder. Ease of application as well as mixing was demonstrated. The coating was air-sprayed to a dry thickness of about 1 mil. To date, the coating has shown no sign of deterioration.

The coating is currently under test at twelve locations: three bridges (two in Maryland and one in California), one chemical plant, two satellite tracking stations, a sounding rocket launch pad in Australia, a boat anchor manufacturing plant, one state and one local public works department, and two paint manufacturing plants.

Tests at the satellite tracking stations are being conducted by the Federal Electric Corporation, a subsidiary of International Telephone and Telegraph, which is responsible for maintaining the antennas at a chain of stations operated by the U.S. Air Force. All stations are located on islands or peninsulas on the Pacific Coast where they are lashed by cold wind and salt spray. Applications of the NASA coating were made in the summer of 1976, and, after 5 months, showed no sign of rust or blistering. Microscopic examination of the steel revealed no corrosion.

On the coast of Australia, a recently erected gantry for the launching of sounding rockets has a coating of the NASA formulation. Figure 1 shows a section of the gantry. This test application requires resistance to fire and thermal shock as well as corrosion. More time is needed to determine the results of this application.

Deicing salts present a corrosion problem for the Public Works Departments of Vermont and the City of Philadelphia. Salt-dispensing trucks received test applications at both locations during 1976. Of particular interest was the coating's hard finish, effective only 30 minutes after application.

All the aforementioned tests are being conducted by potential users of the coating, that is, in the marketplace. Although no final results are available at this time, all test applications look very promising so far.

A market survey was conducted in 1975; an executive summary of this survey is included in Appendix D.

A recent update survey of the raw material manufacturers revealed a cost of $10.70 per gallon for the zinc dust (purchased in 1000 pound quantities) $12.4 per gallon for the potassium silicate solution (5.3 mole ratio), and $0.30 per gallon for the silane, for a total material cost of $12.24 per gallon. With production costs of about $2.85 per gallon, including labor and overhead, the total cost becomes $15.09 per gallon. Since other zinc-rich coatings in today's marketplace range in price from $22 to $43 per gallon, direct from factory to user in quantity shipments, manufacturers of the NASA coating could competitively price the coating and still realize an acceptable profit.

At this time, two manufacturers have been given nonexclusive licenses to produce the coating, and several other license applications are under consideration.

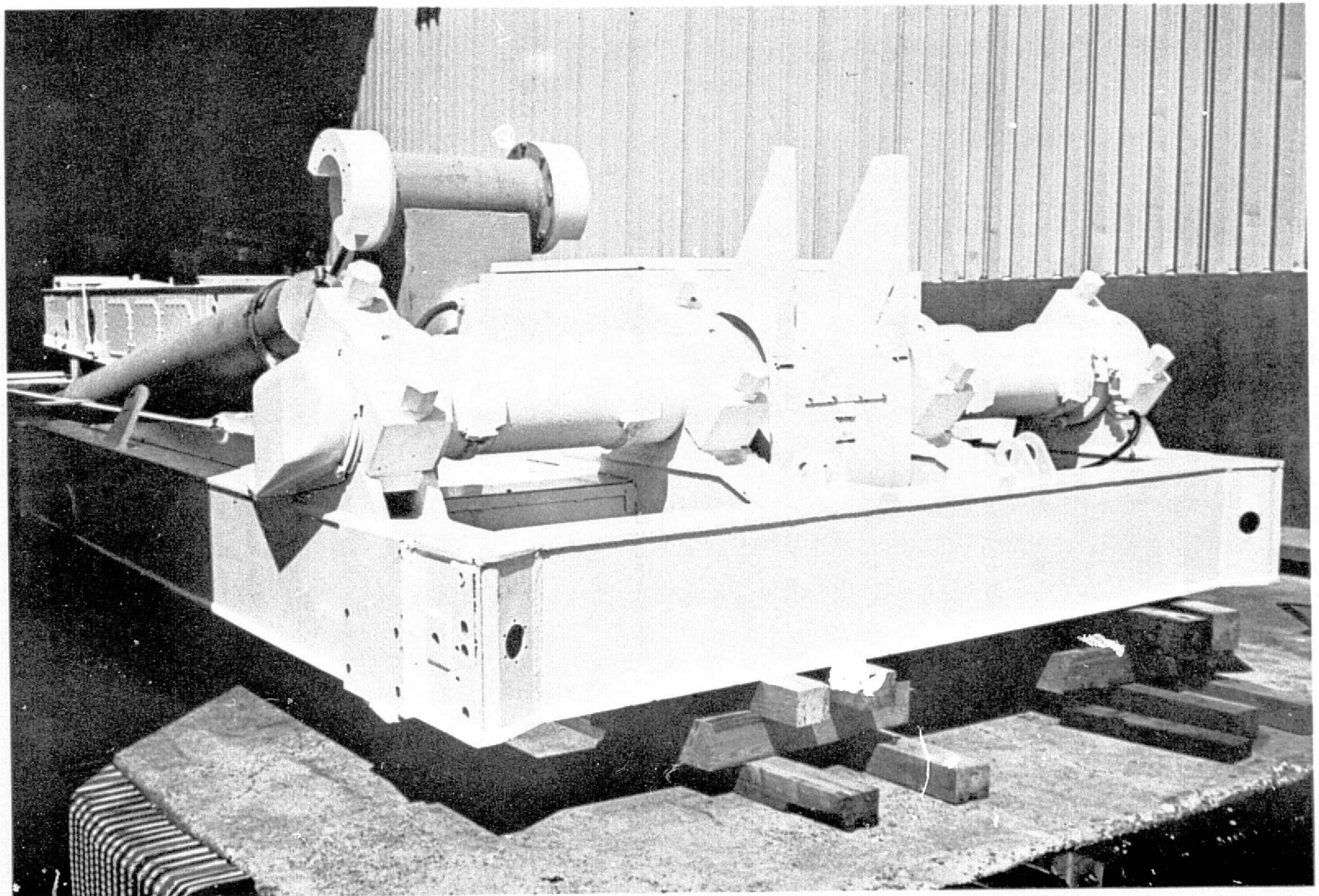

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FIGURE 1 AN AUSTRALIAN GANTRY SECTION COATED WITH NASA'S ZINC-RICH PAINT

AN INEXPENSIVE HIGHWAY SKID TESTER

A primary cause of highway accidents is insufficient tire-pavement friction on surfaces that are unevenly textured, undulating, or wet. Tire-pavement friction as it relates to wet-weather skidding has been a concern of highway officials for some time, and almost all states have begun programs to test their highways for skid resistance qualities. In fact, the Federal Highway Safety Act of 1968 requires that every state have a highway safety program to ensure "pavement design and construction with specific provisions for high skid resistance qualities" and "resurfacing or other surface treatment, with emphasis on sections of streets and highways with low skid resistance. . ." It is our understanding that this act is being enforced on all federally funded roads, which means each state must have the capability of surveying its roads for skid resistance. The United States has a network of 3.8 million linear miles of paved roads, one million of which are on the Federal-Aid System.

Skid resistance is measured with the aid of a skid tester, which is an automotive vehicle having one or more test wheels, torque or force transducers, a signal conditioning and recording system, and actuation controls for braking the test wheel. Currently available skid testers consist of a towing vehicle with a trailer that houses the test wheels. These testers, which range in price from about $30,000 to more than $100,000 depending on size and instrumentation, may be cost-effective for testing primary highways; however, for testing secondary roadways and responding to calls to check accident locations, a smaller model with minimal instrumentation may be more advantageous.

It was found that an inexpensive single-unit Diagonal-Braked Vehicle developed by NASA for testing runways, could also be operated at highway speeds by applying a pulsed braking technique. With diagonal braking, one (unlocked) front wheel is always available for steering and its diagonally opposite rear wheel is free to maintain vehicle lateral stability.

The NASA Diagonal-Braked Vehicle (DBV) is a standard passenger car with a conventional rear axle drive system. During the skid test, it has two (diagonal) wheels rolling free and two (diagonal) wheels locked. All wheels are equipped with ASTM E-501 test tires and speed sensors. The locked wheels are instrumented to measure deceleration during braking, while a fifth wheel monitors distance and velocity. Pulses from this distance-measuring odometer are tallied by a counter, which is actuated by a pressure switch in the brake line when the brakes are applied.

To eliminate the necessity of bringing the test vehicle to a complete stop as described in ASTM Standard E-503, the DBV employs a pulsed braking test method. With this technique, the DBV driver applies the brakes at the desired test speed, locking the diagonally braked wheels. The brakes are released approximately one second after lockup. The resulting vehicle deceleration pulse is measured by a visual reading Tapley meter or by a recording accelerometer mounted near the vehicle's center of gravity. Both longitudinal and lateral measurements are recorded. Figure 2 is a block diagram of the instrumentation. The total cost for vehicle and instrumentation ranges from $5000 to $9500 depending on the system used.

According to the developer of the DBV, Mr. Walter B. Horne of NASA's Langley Research Center, conversion of deceleration measurements to equivalent ASTM skid numbers is simple and straightforward. Because with diagonal braking half of the vehicle is always braking, there is no need for static load distribution and dynamic vehicle pitching moment corrections to the test data. Table II shows the corrections needed to convert Tapley meter deceleration readings to an equivalent skid number. The

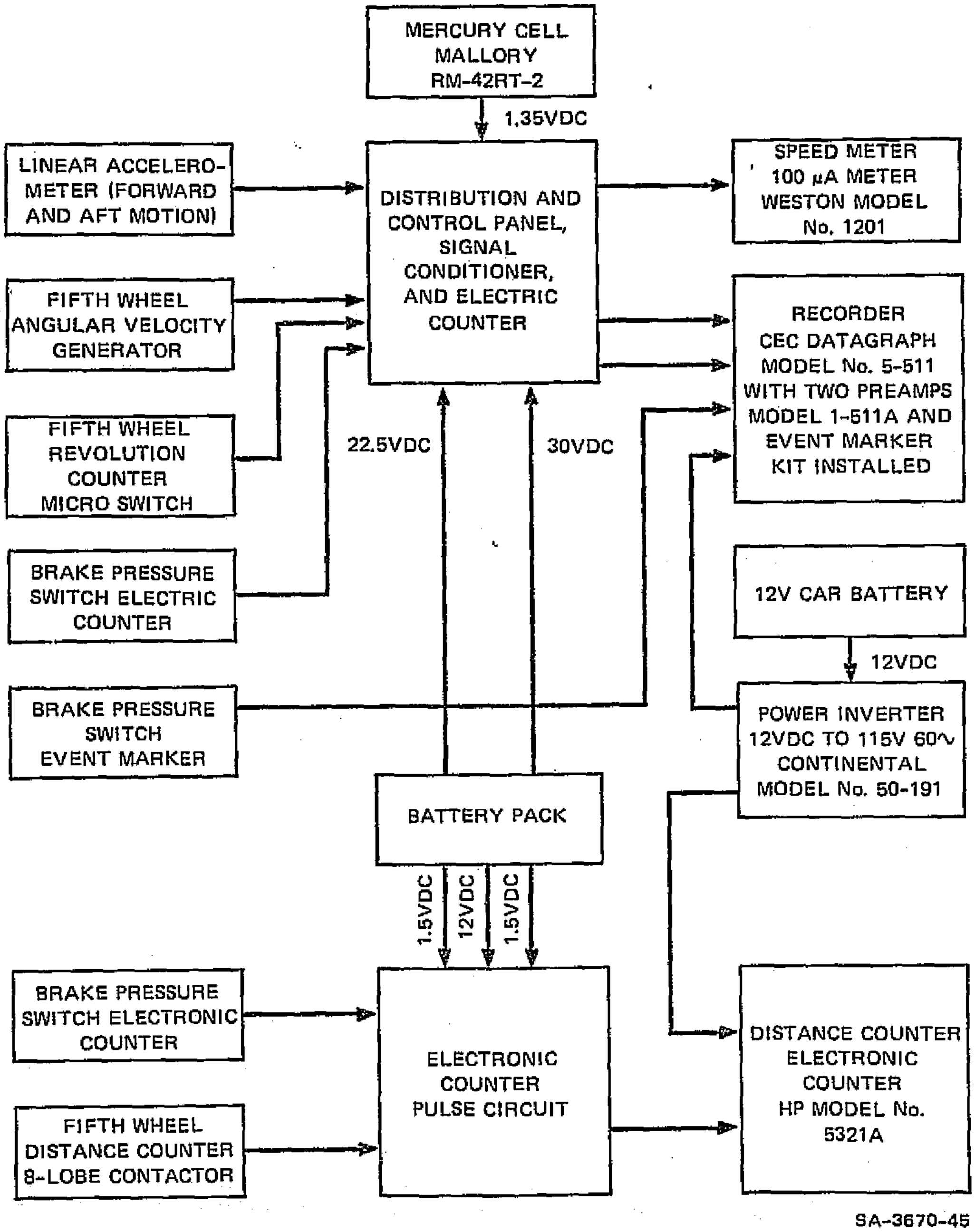


FIGURE 2 INSTRUMENTATION BLOCK DIAGRAM FOR NASA DIAGONAL-BRAKED VEHICLE

Table II

TAPLEY METER DATA REDUCTION FOR DBV

The Tapley number (TN) recorded during the test is converted to an equivalent trailer skid number (SN) by the equation:

$$SN = 2(TN - TT + TS)$$

where

TN = Tapley number from test

TT = Tapley tare correction for vehicle air/rolling resistance

TS = Tapley slope correction for road gradient.

Tapley Tare (TT) Correction		Tapley Slope (TS) Correction		
Vehicle Speed (mph)	TT	Road Gradient (%)	TS Uphill	TS Downhill
0	2	0	0	0
10	2	1	+1	-1
20	2	2	+2	-2
30	3	3	+3	-3
40	3	4	+4	-4
50	4	5	+5	-5
60	5	6	+6	-6

Note: Corrections to Tapley number apply only if the Tapley meter has been zeroed (scale set to zero) while vehicle is at rest on level (zero gradient) road before test.

conversion of recording accelerometer data is even simpler. A line drawn through the recording trace from the start of the braking pulse to its completion delineates the incremental vehicle deceleration. With this data reduction technique, the equivalent skid number is the incremental deceleration multiplied by 200.

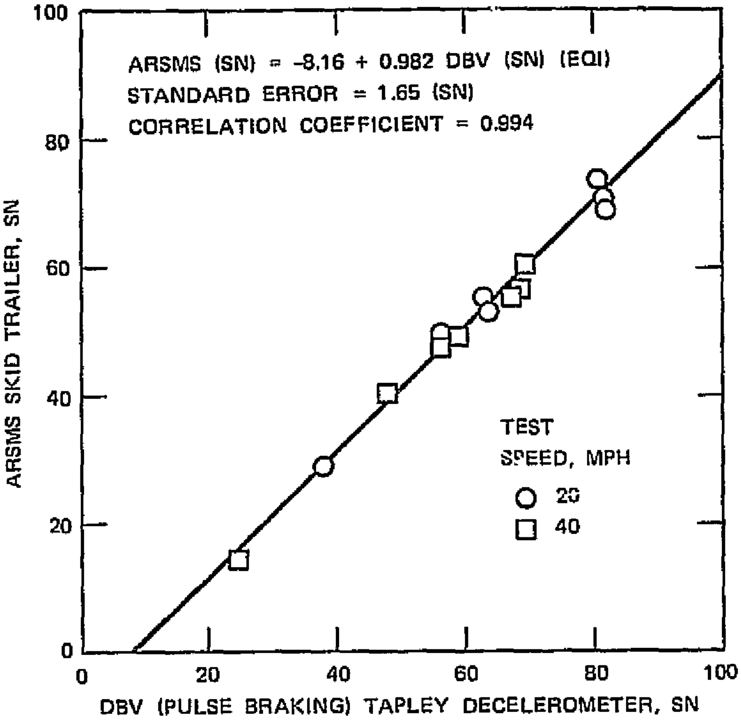
During May 1976, the three-day skid correlation study was conducted at the Texas Transportation Institute in College Station, Texas. NASA's diagonal-braked vehicle and pulsed braking technique were compared with the Federal Highway Administration's new Area Reference Skid Measurement System (ARSMS) skid trailer. Skid resistance measurements were taken on seven different road surfaces, which ranged from a very slick Jennite to a very coarse chip seal.

Fifteen test runs were made on each of the seven road surfaces: five at 20 mph, five at 40 mph, and five at 60 mph. A water truck with a gravity feed water spreader preceded the two test vehicles on each run, wetting the surface with 0.01 and 0.05 inch of water. (Water depth varied with road texture and degree of runoff.) The NASA vehicle followed. Figure 3 shows the comparison test. For one second the brakes were applied, causing the diagonal braked wheels to lock. The resulting skid tracks were carefully noted. Two passes were then made by the comparison test trailer so that its single test wheel could retrace each of the NASA vehicle skid tracks. The comparison trailer had its own water supply to maintain water depth for all passes.

Six measurements of the NASA vehicle were made for each run: velocity of the locked left front wheel, distance of skid, skid speed, velocity of locked right rear wheel, fifth wheel velocity, and acceleration. The deceleration pulse resulting from brake lockup was measured by both the Tapley meter (visual reading) and the recording accelerometer.

Results obtained from the study show a promising correlation between

FIGURE 3 COMPARISON TEST OF NASA DIAGONAL BRAKED VEHICLE FOR SKID RESISTANCE MEASUREMENT



(a) SPEED RANGE 20-40 mph

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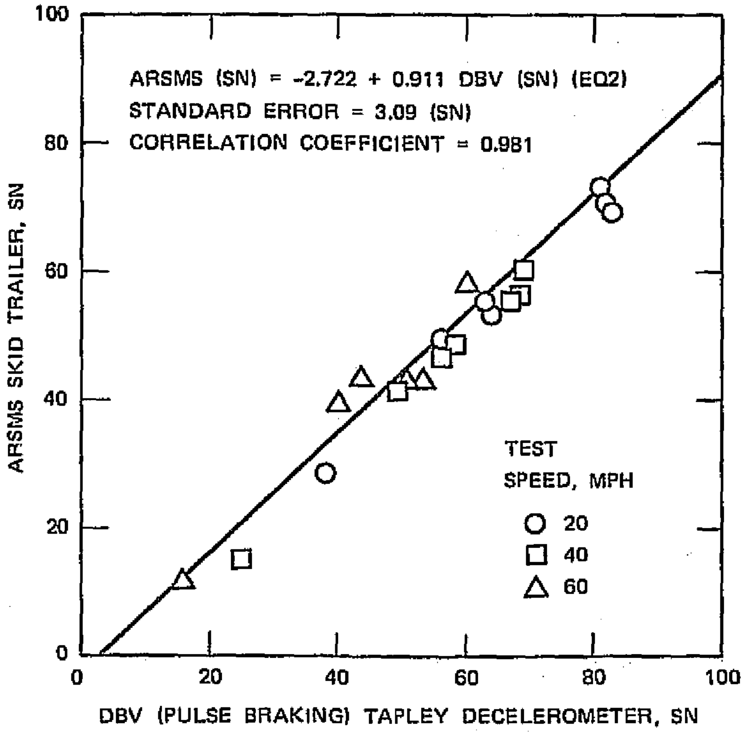

(b) SPEED RANGE 20-60 mph

SA-3670-27

FIGURE 4 CORRELATION BETWEEN ARSMS SKID TRAILER AND DBV, SPEED RANGE 20-60 mph the diagonal braking test method and the skid trailer method. This is especially true in the speed range of 20 to 40 mph, where a correlation coefficient of 0.994 was achieved, as shown in Figure 4. The correlation coefficient was somewhat lower at 0.981 for the entire 20 to 60 mph range.

Transfer of technology such as the DBV can occur only if a market exists for that technology. To determine the market potential for the DBV, SRI conducted a market survey* for NASA. Information collected by SRI from the 50 state highway departments revelas that there are currently 81 skid testers in operation. As shown in Table III, the majority were purchased from K. J. Law Associates (Model 1270) and Soiltest, Inc. (Model ML-350), or were built in-house by the highway departments.

The current market, that is, the number of skid testers needed to meet FHWA requirements, can be readily determined from the statistics on mileage and current capability for each state. We have estimated, based on information collected from the states, that one tester can measure about 2000 miles of highway per month (not secondary roads). This figure is multiplied by the number of months that make up each state's test period, which usually depends on the state's weather pattern. This number (less the number of testers already in use) is shown in Table IV as the SRI minimum estimate. These numbers correspond very well to those provided by the states themselves. Maximum estimates were derived from statistics on the number of regional offices operated by each state's highway department.

The current market appears to be constrained at the state level. Therefore, the total current market for skid testers has a minimum of 72 and a maximum of 249.

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* See Appendix D for Executive Summary of this survey.

Table III

CURRENTLY AVAILABLE SKID TEST EQUIPMENT

Model	Number in Use
Custom design	16
K. J. Law 1270	23
K. J. Law 965A	8
Soiltest ML-350	16
Soiltest ML-355	2
Mu-Meter	7
Other	9
Total	81

Table IV

CURRENT MARKET FOR SKID TESTERS

State	Federal-Aid System* State Roads†	Federal-Aid System* County Roads	Current Number of Skid Testers	Market Estimated by State Highway Depts. If $10,000	Market Estimated by State Highway Depts. If $5,000	Market (under $10,000) Estimated by SRI Team Min.	Market (under $10,000) Estimated by SRI Team Max.
Alabama	7,200	15,000	1	2	2	2	3
Alaska	1,700	2,400	0	1	1	1	2
Arizona	4,400	3,400	2	1	4	0	2
Arkansas	4,000	14,100	2	1	1	1	6
California	11,600	13,200	3	0	0	1	10
Colorado	5,000	4,400	1	0	1	1	10
Connecticut	1,300	900	1	0	0	0	3
Delaware	500	1,300	1	0	0	0	1
Florida	5,400	13,000	4	6	6	0	4
Georgia	8,600	19,600	2	2	2	2	6
Hawaii	500	400	1	0	0	0	1
Idaho	3,600	5,600	1	0	0	1	4
Illinois	13,800	14,200	1	2	4	4	16
Indiana	5,600	17,300	2	2	6	2	10
Iowa	9,900	32,900	3	1	2	2	10
Kansas	8,000	24,200	1	5	6	4	11
Kentucky	4,600	14,500	2	0	0	0	4
Louisiana	3,000	8,600	2	0	0	0	3
Maine	2,000	2,500	1	0	0	0	3
Maryland	1,700	6,600	3	0	0	0	2
Massachusetts	2,900	1,200	1	8	10	2	7
Michigan	6,000	25,000	2	1	1	1	10
Minnesota	7,700	30,000	2	0	0	2	12
Mississippi	6,500	16,100	1	1	1	2	5
Missouri	8,200	23,500	1	0	0	2	10
Montana	7,400	5,900	1	1	1	1	6
Nebraska	6,300	17,400	2	0	0	1	7
Nevada	2,800	3,500	1	0	0	0	1
New Hampshire	1,300	1,600	0	1	2	1	3
New Jersey	2,200	1,200	3	3	4	0	3

*Urban figures not included.
†Interstate roads included.

Table IV (Concluded)

CURRENT MARKET FOR SKID TESTERS

	Federal-Aid System*		Current Number of Skid	Market Estimated by State Highway Depts.		Market (under $10,000) Estimated by SRI Team	
State	State Roads†	County Roads	Testers	If $10,000	If $5,000	Min.	Max.
New Mexico	4,600	5,900	1	0	0	1	2
New York	8,600	12,000	3	10	12	2	12
North Carolina	4,600	27,700	1	1	1	2	7
North Dakota	5,200	14,000	1	3	5	2	10
Ohio	6,800	18,900	3	0	0	1	9
Oklahoma	5,900	15,700	1	2	3	2	8
Oregon	4,200	8,700	1	1	1	1	6
Pennsylvania	7,900	12,000	4	0	0	1	8
Rhode Island	500	300	1	1	2	0	2
South Carolina	5,200	21,000	1	1	1	3	5
South Dakota	6,400	13,700	1	0	5	3	10
Tennessee	6,700	11,500	2	5	9	2	8
Texas	16,800	39,600	4	0	7	6	16
Utah	3,100	4,000	1	2	2	1	3
Vermont	1,700	2,000	0	1	2	1	3
Virginia	4,600	19,000	2	2	7	3	7
Washington	4,300	10,400	2	0	0	1	6
West Virginia	3,000	10,700	2	2	5	1	3
Wisconsin	6,800	18,000	1	1	1	4	9
Wyoming	4,700	2,700	1	0	0	1	5
All States			81	75	117	72	249

*Urban figures not included.
†Interstate roads included.

With the growing public concern for safe roads and the increase in accident claims against state and local agencies responsible for maintaining the roads, the states may decide that all paved roadways should be tested annually or biannually for skid resistance. Such a widespread test program might best be carried out at the county level, provided the costs were not prohibitive. As shown in Table V, this represents a potential future market for 3,026 inexpensive skid testers.

SRI Team efforts led to the scheduling of a demonstration of the DBV and pulsed braking technique for the Federal Highway Administration, to be held in early 1977. The FHWA is considering the DBV primarily for use in accident investigations, to determine if low pavement friction is a contributing factor. A successful demonstration in 1977 should lead to the involvement of many state and local governments in subsequent tests and purchase of skid testers based on the NASA design.

Table V

ESTIMATED MARKET FOR SKID TESTERS

TO TEST ALL PAVED ROADS

	Number of Units	Cost Per Unit	Total Dollar Market
State program	75	$60,000	$ 4,500,000
	249	$10,000	$ 2,490,000
Regional program	750	$60,000	$45,000,000
		$45,000	$33,750,000
		$10,000	$ 7,500,000
County program	3,000	$25,000	$75,000,000
		$10,000	$30,000,000
		$ 5,000	$15,000,000

A NOVEL HIGHWAY CRASH CUSHION

Fixed appurtenances existing along the nation's highways--such as bridge piers and abutments, heavy sign supports, retaining walls, and the like--present serious hazards to the wayward motorist or the occupants of an out-of-control vehicle. To reduce the severity of collisions with these objects, highway departments have installed impact attenuating systems of sand filled plastic barrels, steel drums, water-filled plastic tubes, frangible tubing, rubber tires, or crushable cannisters. Many currently installed systems are as unyielding and dangerous to the driver and vehicle (especially in the case of small cars) as the appurtenances they protect.

The SRI Team believed NASA's experience with impact attenuating devices for extraterrestrial landings could be applied to the highway problem. Of particular interest was a concept (Tech. Brief 72-10712) developed at NASA's Jet Propulsion Laboratory (JPL) wherein a large number of contiguous cylinders, arranged in multiple strata, would slow an impacting vehicle by sequentially crushing. The impact force would be dissipated in a controlled manner for smooth vehicle deceleration.

A program based on this concept was initiated in 1975 to develop a safe crash cushion. Various materials and configurations were comparison-tested for energy dissipating characteristics; materials included glass, steel, aluminum, polypropylene, and polyethylene. As shown in Table VI, the technical criteria used in determining energy dissipating characteristics were the energy dissipated in crushing the material/configuration (E_D), the associated average crushing stress (σ_{CR}), the energy-dissipation density (E_D), and the stroke efficiency (E), which is the ratio of the "bottoming out" stroke to the original length. In addition, cost factors were estimated, the most interesting being the amount of crushable energy that could be dissipated for one cent (E_D).

Table VI

EVALUATION OF ENERGY-DISSIPATING CHARACTERISTICS OF VARIOUS MATERIALS

Category	Item	Material	Energy-dissipating characteristics				Cost factors	
			E_D, in./lb	σ_{CR}, lb/in.^{2}	$\bar{E}_D$, in.-lb/in.^{3}	ϵ, %	C_U, $ est.	E_D, in.-lb/¢
Drums (Refs. 2 and 3)	55-gal drum	Steel	108,000	8	9	71	10.00	108
Spheres	Sphere, 2.5" diam x 0.035" wall	Glass	8	1	1	98	0.50	0
	Lightbulb, 2" diam x 0.020" wall	Glass	4	1	1	98	0.30	0
	Sphere, 4" diam x 0.040" wall	Polypropylene	590	15	18	80	0.80	7
	Sphere, 4" diam x 0.040" wall	Polyethylene	720	18	22	80	1.00	7
	Sphere, 8" diam x 0.065" wall	Steel	77,500	25	290	81	10.00	78
	Sphere, 4" diam x 0.040" wall	Aluminum	4850	97	135	83	5.00	10
	Sphere, 8" diam x 0.025" wall	Aluminum	6500	20	25	79	5.00	13
	Sphere, 13.5" diam x 0.065" wall	Aluminum	83,000	50	65	86	10.00	83
Disposable containers	12-oz beverage can	Aluminum	560	24	23	76	0.03	190
	12-oz beverage can (axial)	Aluminum	340	8	14	72	0.03	110
	16-oz beverage can	Aluminum	530	14	18	83	0.03	180
	12-oz beverage can	Steel	980	35	43	83	0.03	330
	12-oz beverage can (axial)	Steel	1340	27	53	80	0.03	450
	30-lb refrig can	Steel	67,000	90	95	83	0.50	1340
	8-oz beverage bottle	Glass	12	1	1	95	0.06	1
Other	4" diam cylinder float	Copper	460	10	46	82	4.00	1
	3" diam muffin cup	Aluminum	140	7	5	92	0.03	47
	2" domed cylinder	Steel	9200	960	1010	66	0.60	150
	4 x 6 x 4" deep block; 1 lb/ft^3	Styrofoam	1400	19	14	77	0.056	250

E_D = usable energy dissipated.

σ_{CR} = average crushing stress (avg. crushing force/max. cross-sectional area).

$\bar{E}_D$ = energy dissipated per unit volume.

ϵ = stroke efficiency.

C_U = estimated unit cost.

E_D^* = energy dissipated per penny.

With regard to performance and cost, the metal disposable beverage cans appeared to have the greatest potential application. Specifically, it was determined that the same amount of energy dissipated by crushing a 55-gallon steel drum could be dissipated by crushing an array of 325 beverage cans of one-third the volume, at the same cost. This is important, because space limination is an important consideration in placing crash cushions.

A prototype system was fabricated and laboratory tested at JPL. Three modules of graduated size were crushed both axially and at a 25° angle. As shown in Figures 5 and 6, the beverage cans crushed sequentially.

Field tests of a full-scale model are scheduled for early 1977--the first to be conducted at JPL and the second at the California Department of Transportation test track near Sacramento. Arrangements for the state test are being made by the SRI Team. In both tests, a six-module crash cushion will be impacted by a medium-weight passenger car, with the first test at 30 mph and the second at 45 mph. Tests will be conducted in accordance with National Cooperative Highway Research Program Report 153, "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances".

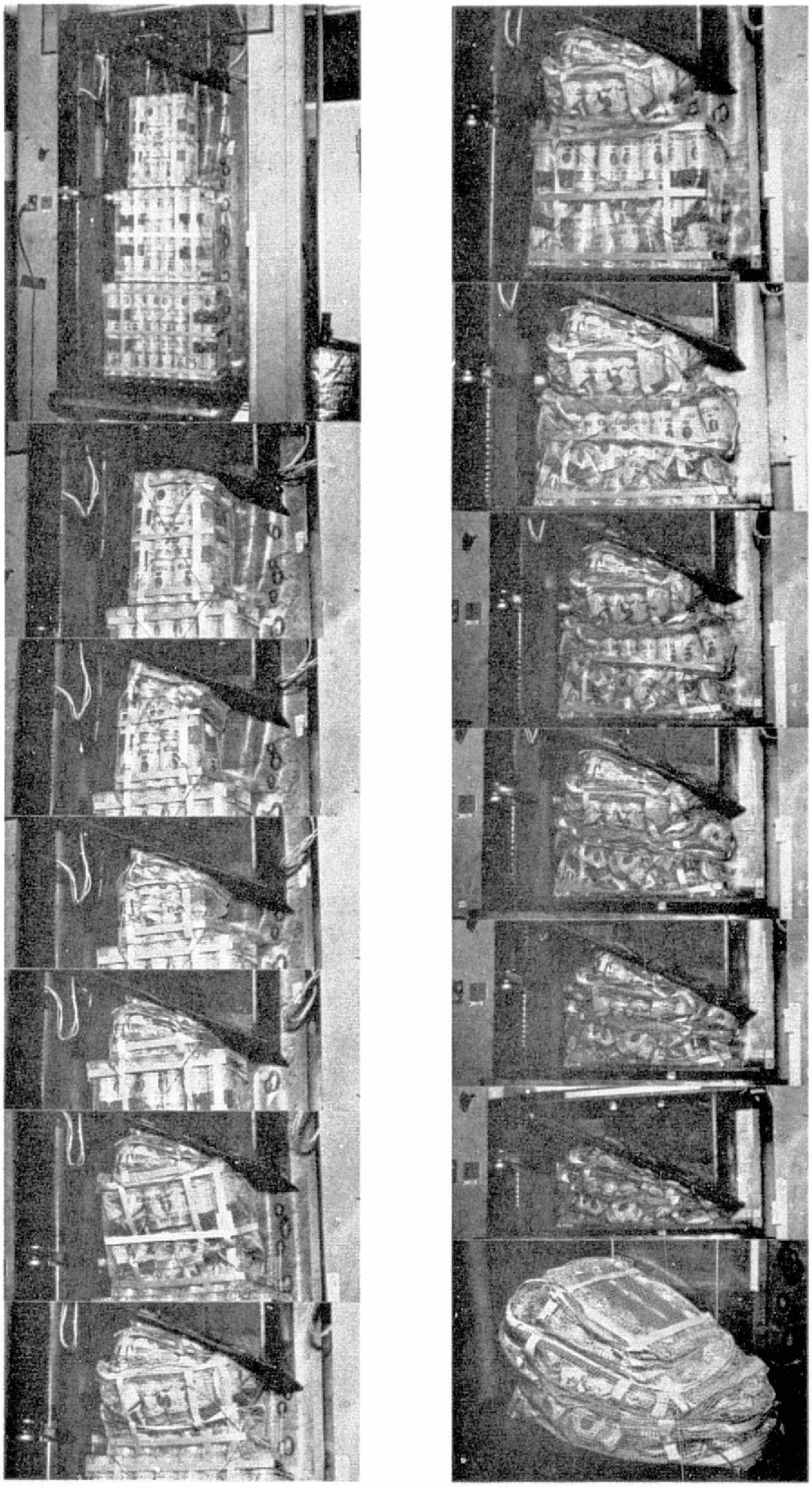

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FIGURE 5 LABORATORY TEST OF JPL CRASH BARRIER (25° ANGLE)

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FIGURE 6   LABORATORY TEST OF JPL CRASH BARRIER (AXIAL) is based on a hydrophilic polymer that allows water to contact, dissolve, and mix with the chemiluminescent component, but is insoluble in water itself. To date, the period of the paint's luminescence has been extended from several minutes to several hours.

The system was demonstrated successfully to the Federal Highway Administration at a program review meeting held on 16 October, 1976 in Charlottesville, Virginia. Team member Ruth M. Lizak attended the meeting and discussed the future direction of the program with appropriate FHWA personnel.

The system must be refined to increase brightness before a prototype can be developed for highway test application. SRI Team contacts with state highway departments revealed that when this refinement is completed, several departments would welcome the opportunity to conduct the necessary field tests, now tentatively scheduled for later in 1977.

A BRIDGE-ICING ALERT SYSTEM

Numerous skidding accidents on bridges occur because patches of ice and frost can form on bridge decks at a time when the approach pavements are frost-free. Road safety is dependent to a large extent on the driver's awareness of the highway environment. On icing bridges, driver awareness depends on some kind of warning system, and this system must be individual for each bridge because each has its own microclimate. Recognizing this microclimate, many developers have built their systems around temperature/humidity sensors that are either mounted on the road surface or imbedded in the pavement. Unfortunately, these sensors may sustain damage or retain moisture, causing fraudulent readings. Other approaches based on accoustic measurement of ice or detection of latent heat diffusion have also been unsuccessful.

A system capable of accurately predicting icing conditions on bridge decks is currently being developed. It comprises an infrared detector developed in 1976 at NASA's Ames Research Center for remotely sensing temperatures on the planet Venus, combined with a dewpoint hygrometer. In the NASA system, deck temperature is sensed remotely by an infrared radiometer that is attached to a structural member or guardrail. The analog voltage from the radiometer, which corresponds with deck temperature, is fed to the chilled crystal of a dew point hygrometer, (also located above the deck), which tracks the road temperature. Dew or frost forming on the crystal when the road temperature is $0^{\circ}C$ or below produces an analog signal, which triggers the alert.

NASA's remote sensing technique has attracted the attention of several state highway departments in the Northwest, and they have offered to conduct field tests. Before field testing is considered, however, instrument reliability will be tested in the environmental chamber at the NASA-Ames laboratory. The test program has been approved and is scheduled for early 1977. Following the successful completion of a one-month environmental test, the instrumentation will be fitted with a vandal-proof housing for roadside operation and arrangements will be made for installation on an ice- or frost-afflicted bridge.

SOIL MOISTURE ANALYSIS TO PREVENT ROAD COLLAPSE

Road collapse, a serious highway problem, results from poor compaction of the road beds prior to road construction. Proper compaction depends on the mechanical responses of the soil to various loading levels. Because such responses are moisture-dependent, accurate soil moisture measurements must be made to insure proper road-bed compaction.

A survey of the market by the SRI Team revealed that all currently available systems are either slow or inaccurate, or both, or require the handling of radioactive materials. This conclusion was confirmed by FHWA researchers. The slow techniques consider weight differences before and after moisture removal, and require overnight drying in an oven. Not only is this time consuming, but also it may result in inaccurate measurements, because the soil's moisture content may change from one day to the next. Additional inaccuracies are caused by instruments that can handle only very small soil samples. Because most soils are heterogeneous and may contain large agglomerated particles, small samples may give incorrect readings.

During 1975, the SRI Team learned of a simple and rapid analytical technique developed as part of the Viking (and post-Viking) program for determination of soil moisture content. At NASA's Ames Research Center, researchers were conducting soil moisture analyses by extracting soil with methanol and subsequently analyzing the extract for water by gas chromatography. After addition of the chromato-quality methanol, the soil sample was centrifuged at 1200 rpm for about 30 minutes to sediment the soil particles. Analysis for water was made of the supernate using an inexpensive, dedicated gas chromatograph to give a typical trace as illustrated in Figure 7. In comparative tests conducted at NASA-Ames, moisture measurements made with this technique closely matched those

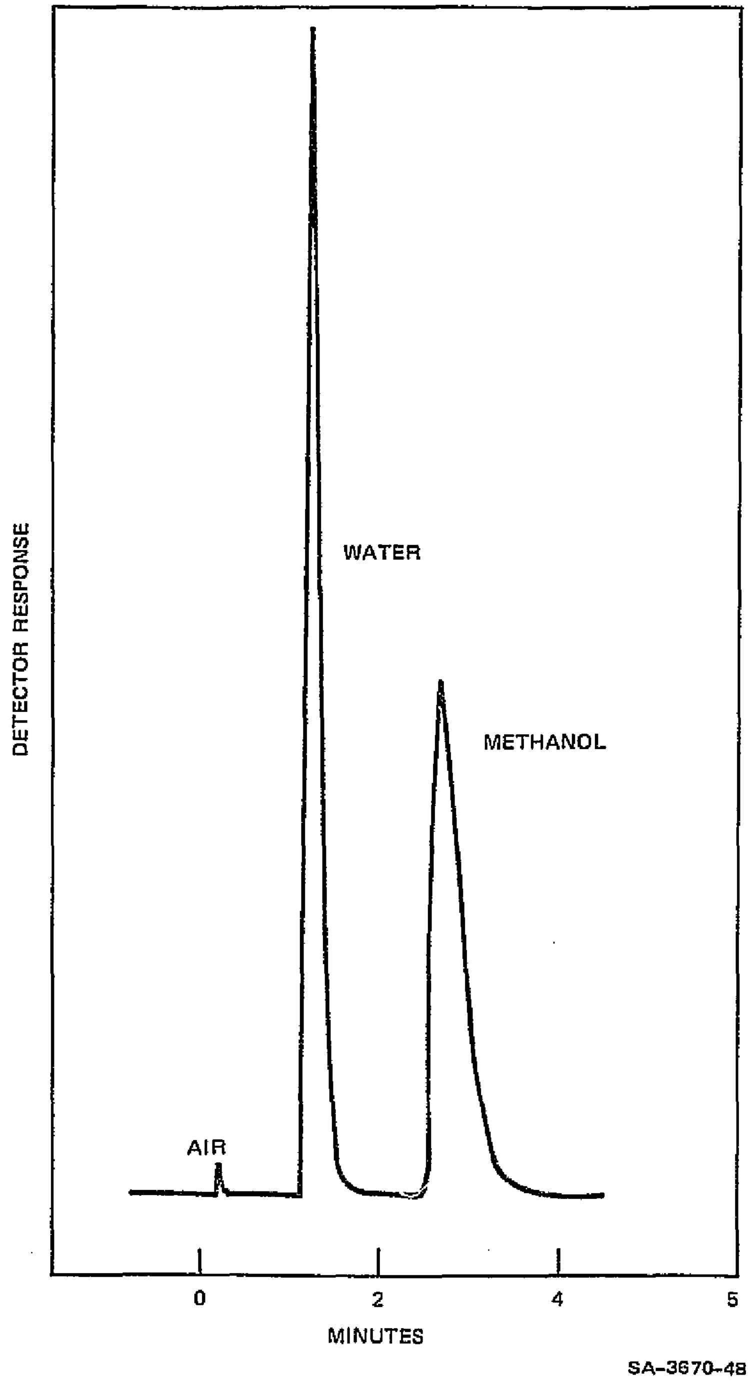

FIGURE 7 CHROMATOGRAM OF A WATER-METHANOL MIXTURE

those determined by oven drying. However, the NASA procedure, including extraction and analysis, required less than 1 hour, whereas oven drying required 8 hours.

The SRI Team informed the Texas, California, and Washington State Highway Departments of this procedure. All three states expressed interest in the technique, and Texas offered to conduct field tests if a portable model were developed. Such a model must be "highway-proof", for use in the field.

In 1976, a program was initiated at NASA-Ames to design and build a model that is not only rugged but also easy and safe to operate by field personnel. Preliminary cost analyses indicated a competitive price.

Field testing by Santa Clara County (California) public works personnel is scheduled for early 1977, coinciding with an evaluation by the Federal Highway Administration. Should the system be capable of handling large samples, which seems assured, the FHWA will appropriate documentation for dissemination to all state highway departments.

A NEW BRAKE FRICTION MATERIAL

User interest in dependable brake materials for lightweight trucks and automobiles resulted in adaptation of a novel composite material developed by NASA's Ames Research Center for supersonic transport brake lining. This material exhibited an essentially constant coefficient of friction with temperatures ranging as high as 650°F and an average coefficient of friction of approximately 0.34. A comparison of the change in coefficient of friction as a function of temperature for the NASA material and conventional brake lining materials demonstrated the superiority of the NASA material at temperatures greater than 400°F. At these higher operating temperatures the NASA material's coefficient of friction actually increased, whereas that of conventional brake linings decreases markedly. Wear improvement at elevated temperatures was also noted.

These properties were achieved solely through the replacement of asbestos by a particular potassium titanate fiber and through formulation adjustments from the optimized standard. Potassium titanate exhibited a number of superior properties. At temperatures as high as 1000°C, there was no detectable weight loss and X-ray studies indicated no detrimental changes of the material at this temperature. (For example, products of thermal exposure are no harder than unheated material.) More pronounced improvements would be expected under conditions of relatively severe use.

In addition, the excellent wear characteristics of the NASA material were demonstrated in test programs conducted by the National Highway Traffic Safety Administration (NHTSA). After 4 hours at 800°F in the Friction Material Testing Machine, wear loss of the NASA material was only 0.06 inch, compared to losses of 0.14 to 0.25 inch with other friction materials tested by NHTSA. No sign of wear or abrasion was visible to the unaided eye. The coefficient of friction was again found to be approximately 0.34. A full-scale dynamometer test, conducted by the Bendix Corporation, confirmed the stability of the NASA material's coefficient of friction at high temperatures and an average coefficient of friction of approximately 0.34.

Data gathered by the SRI Team during a market survey* indicated that the bus brake market had the highest potential for the successful entry of a new brake friction material. The following improvements were required over conventional linings:

- Reduced noise during braking
- Reduced fade, more stable coefficient of friction at elevated temperatures
- Reduced lining wear
- Reduced drum wear
- A price comparable to or no more than 40% higher than conventional linings.

Market size was estimated at 750,000 to 800,000 pieces per year (original equipment) and as high as 8.0-8.2 million pieces per year (replacement). This represented a yearly market of $22-27 million.

The market chosen as the second most favorable for the penetration of a new friction material was the heavy truck brake lining market. Rising labor costs and increased federal legislation had increased the industry's awareness of its need for such new materials. The original equipment market for truck linings in 1975 was estimated to be approximately 8.0-8.5 million brake blocks at a market value of $20-21.3 million. An additional 1.46 to 1.49 million pieces at a value of $3.65 million to $3.75 million were estimated sold for use on new trailers manufacturers in 1975. The replacement for brake linings for trucks and trailers was estimated as 9.50 to 10.25 million brake blocks at a value of $23.8 to $25.6 million.

* The market surveys conducted during this report period are summarized in Appendix D.

Although a considerably more detailed study than was possible in this survey is necessary to accurately determine the size of the market, it appeared that improved brake friction materials are also needed in the industrial equipment sector. This category includes equipment such as overhead cranes, hoists, and the like and represents an overall brake lining market value estimated at $80-100 million annually.

Other areas studied were passenger cars, light trucks, heavy trucks and truck/trailers, rail cars, and light aircraft. Estimates of the brake lining market for these sectors are given below:

Vehicle Type	Market	Volume Pieces/ Year (000)
Passenger Cars	Original Equipment	72,000-73,000
	Replacement	210,000-220,000
Light Trucks	Original Equipment	16,000-18,000
	Replacement	22,000-24,000
Trucks	Original Equipment	8,000-8,500
	Replacement	4,000-4,250
Trailers	Original Equipment	1,460-1,490
	Replacement	5,500-6,000
Buses	Original Equipment	750-800
	Replacement	8,000-8,200
Rail Cars		3,290
Light Aircraft		600

Market entry into these sectors is strongly limited by lining cost, because a very strong technical advance over current materials would be required to justify any additional lining cost. We believed that the NASA material did not exhibit these advances, and thus market penetration in these areas was not anticipated.

The SRI Team interested the Abex Corporation, a major brake manufacturer, in the NASA brake lining technology. However, when Abex started to consider a developmental program for the manufacture of proto-

A PAVEMENT STRIPING MATERIAL THAT FLUORESCES FOR RAINY NIGHT VISIBILITY

Pavement striping is least visible when it is needed most--on rainy nights, when visibility is decreased and when an emergency maneuver may cause skidding. The problem of nighttime delineation in dry weather was solved with the general acceptance of glass bead-filled paints for traffic marking more than 30 years ago (as long as the beads remain intact). However, even when newly applied, these beads lose their reflectivity under wet conditions. Pavement markers were introduced about 10 years ago, but they are very expensive and are effective only in areas where snow removal equipment is not needed. Nighttime delineation in wet weather is still a problem today.

The SRI Team was aware of a research program at NASA's Goddard Space Flight Center to formulate a moisture-activated chemiluminescent material. For highway use, the formulation would have to be developed further to extend the period of luminescence, and would have to be incorporated into a paint system. The Federal Highway Administration's belief that the idea had merit was confirmed by its willingness to fund this requisite development. The program objective was to provide FHWA with a paint system that could:

(1) Provide a brightness of 0.5 ft. lbt.

(2) Be activated by rain, but return to dormancy when dry.

(3) Have a useful life of several months.

(4) Extend no more than 15 mil (0.0381 cm) above the pavement.

(5) Limit the luminescence to the area of application.

During the two-year development program, carried out in 1975 and 1976, a water-soluble oxalic ester paint formulation was developed. The oxalic ester acts as the chemiluminescent agent. The paint formulation type brake linings using the ARC material, the Team discovered that the sole supplier of the key ingredient--potassium titanate--the DuPont Company, had decided to withdraw the material from the market. Subsequent discussions with DuPont representatives revealed this to be a firm corporate decision with no possibility of recourse. As no other manufacturer appeared interested in producing the potassium titanate necessary for the NASA formulation, transfer activities were halted and the problem was retired from the active list. The project is discussed in this report to illustrate that (1) not all transfer projects are successful, even if the technology is sound, (2) early user involvement is critical for successful transfer operations, and (3) unforeseen and extenuating circumstances can dramatically effect the course of a transfer project.

PRELIMINARY HIGHWAY PROBLEMS

Problems that have been identified by the highway departments for future investigation by the SRI Team include traffic signals for the blind and more effective guardrails for the highways.

Traffic Signals for the Blind

The self-sufficiency of the blind is dependent on their mobility, which requires that they be able to cross major thoroughfares safely. Although traffic signals with an audio feature for the blind have been developed, the signal is often inaudible when the traffic or other environmental noise level is high, and is disturbingly audible under the reverse conditions. During its space program, NASA has developed warning systems that are neither visual nor audial, and these will be considered by the SRI Team. Of particular interest is the tactile research that has been conducted at NASA's Ames Research Center. With a tactile system, a blind pedestrian could wear a receiver that could be activated by the traffic signal to alert him of safe conditions for crossing.

More Effective Highway Guardrails

New construction of public roads requires approximately 6300 miles of guardrails and median barriers per year and about 900 miles of new bridge rails. No statistics are available on the miles of rail needed for replacement of damaged or inadequate systems. At present, however, rails are designed to retain vehicles in the 2000-4500 pound weight range only. Thus, buses and trucks are too heavy as well as to high to be retained by systems currently on the market. Accident statistics on heavy vehicle collisions and truck/bus driver and passenger fatalities indicate the need for improved systems. Moreover, the two most common types of fatal accidents--the ran-off-road accident and the vehicle-vehicle collision--could be significantly curtailed by improved guardrail systems.

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NASA has developed both systems and materials for high impact applications. Efforts by the SRI Team will be directed toward uncovering candidate systems and bringing them to the attention of highway engineers.

III RAILROAD PROBLEMS

A ROLLER BEARING FAULT DETECTOR

Railroads are currently effecting the changeover from the commonly used journal wheel bearing to the more efficient roller bearing. Since 1968, all new and rebuilt railcars have incorporated roller bearings. Today, approximately 10 million roller bearings are in service, which constitutes approximately 65% of the railroad car fleet. Although the change has been beneficial to operations, unanticipated problems have also surfaced. After periods of wear, or in the case of undetected flaws, all bearings will fail. However, unlike journal bearings, roller bearings will not exhibit a long temperature rise prior to failure, and thus their impending failure will not be detected by standard techniques. This inability to detect incipient wheel bearing failure has been identified as one cause of railcar derailments. Approximately 360 train accidents and $10 million in damages are caused each year by broken wheel bearings.

When the SRI Team learned of this problem from the Association of American Railroads, it reviewed available NASA literature in the non-destructive testing field and uncovered a high frequency vibration diagnostic technique used by NASA scientists to detect faults in rolling element bearings (NASA Tech Briefs 72-10494 and 72-10689). Although the technique was originally developed under a NASA-supported program for use in evaluating ball bearing defects in a control moment gyroscope, the approach appeared suitable for detection of faults in railroad wheel roller bearings.

The technique relies upon the fact that damage existing in the race-ways or cage areas induces structure-born vibration in the high-frequency range (10 kHz to 50 kHz) as well as in the low-frequency range (2 kHz to 10 kHz). Damage is more readily discerned in the high-frequency range and the damage source can be identified by studying the amplitude time history of the high-frequency vibration.

The SRI Team related the railroad problem to the innovators of the technique who are currently employed by Shaker Research Corporation, Ballston Lake, New York. Data obtained by a laboratory breadboard bearing fault detector (incorporating a high-frequency band pass filter and demodulator) applied to automobile wheel bearings were compiled in a technical R&D report. The report was submitted by the SRI Team to the Association of American Railroads (AAR) for their evaluation as to potential applicability of the technique to railroad wheel bearings. The AAR's evaluation was positive and railroad equipment and assistance were offered for testing purposes.

The application of the technique for the development of a bearing fault detector for tapered roller railroad wheel bearings was initiated through an adaptive engineering program co-funded by Shaker Research Corporation and the NASA Technology Utilization Office. The seven-month program began in May 1975. The primary objective of the program was to prove feasibility for the application of the NASA-developed, high-frequency vibration technique for railroad use by (1) analyzing railroad rolling element wheel bearing faults, (2) building a prototype fault detector based on this analysis, and (3) conducting field tests of the fault detector on a railcar truck wheel assembly.

During 1974 and 1975, the Team maintained close liaison with Shaker Research Corporation and the AAR. As a result, the AAR had their own technical monitor review progress of the adaptive engineering program, supplied Shaker Research Corporation with a wheel bearing puller, and worked with Shaker Research Corporation engineers during the field test program conducted at the AAR's Technical Center in Chicago. The field test program utilized the AAR's grease test fixture (Figure 8) to simulate speeds up to 50 mph and a railcar truck (Figure 9) for track

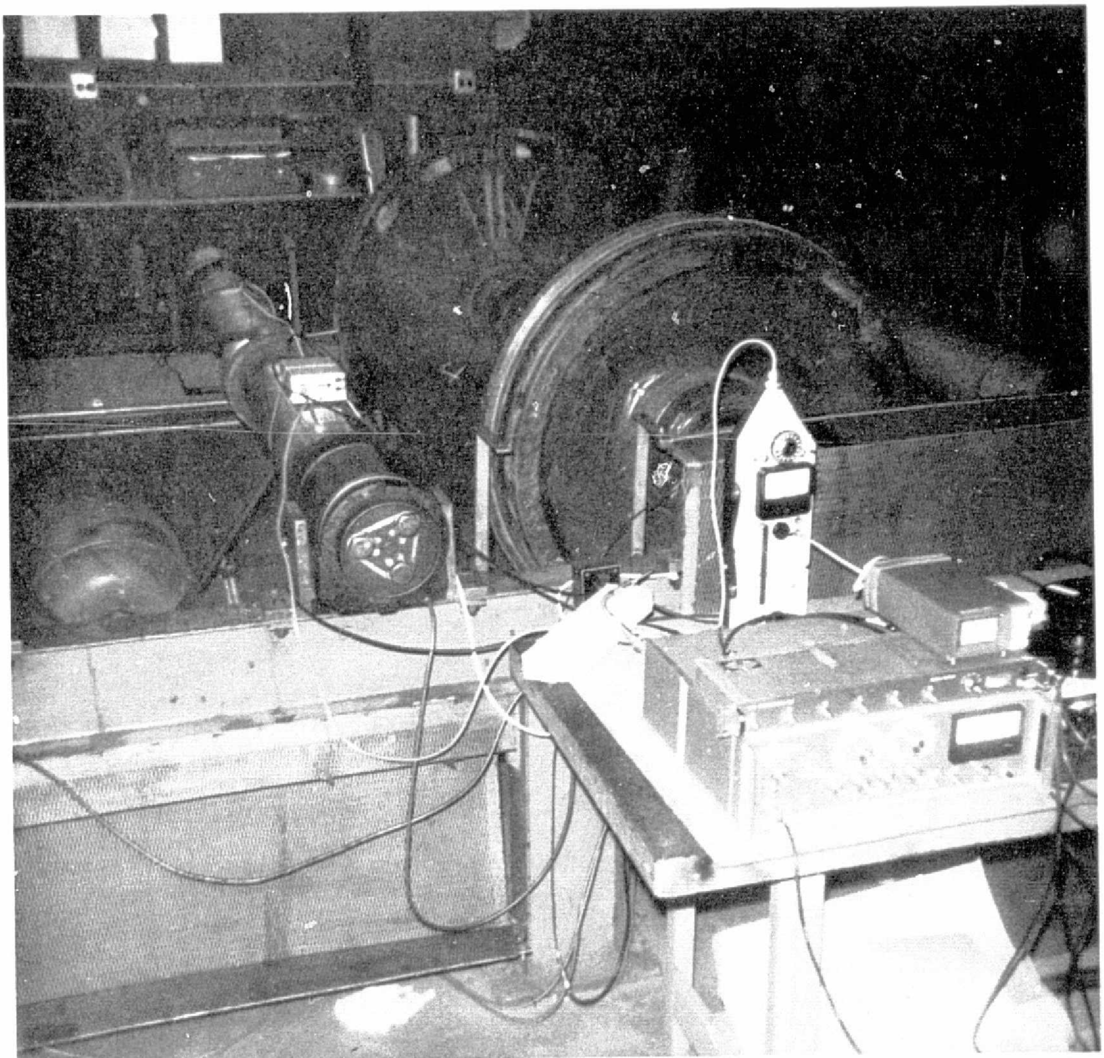

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FIGURE 8 BEARING FAULT DETECTOR: TESTING AT THE AAR TECHNICAL CENTER

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FIGURE 9 ROLLER BEARING TEST INSTRUMENTATION ON A RAILCAR TRUCK testing of the field detector box.

The project was completed by December 1975. Appendix E contains a description of the fault detector prototype used, the summary of results, conclusions, and recommendations, as written in the final report.[4]

When the SRI Team first identified the NASA/Shaker Research Corporation high-frequency vibration diagnostic technique as being potentially applicable for railroad use, the Team introduced the technology to the DoT's Transportation Systems Center (TSC). As a result, TSC awarded a contract to Shaker Research Corporation for a railroad roller bearing certification and diagnostics program. The TSC program began with a short study of all candidate bearing diagnostic techniques to determine which ones might be combined for use in a bearing certification test procedure. The NASA technique in conjunction with several supportive techniques appeared feasible for this purpose. In addition, Shaker Research Corporation defined a new bearing certification procedure to be based upon experimental analysis and performed a detailed cost-benefit analysis. TSC plans also called for combining several techniques into a diagnostic instrument that might be used in a railroad wheel rework shop.

In Spring 1976, Shaker Reserach Corporation tested the NASA/Shaker roller bearing fault detector by correlating device readings with the results of visual inspection of dismantled bearings after removal from the test rig. The tests were conducted at the Southern Railway System wheel shop and the Brenco, Inc., (a bearing manufacturer) rework facility in Knoxville, Tennessee.

As a result of this and other tests under the TSC-sponsored project, Shaker Research Corporation is continuing to improve the development to meet railroad standards of reliability, adaptability, durability, ease of operation, and cost. Currently, it is estimated that the NASA/Shaker device could be used by railroads in the following ways:

- At a siding or repair track following a derailment, for measuring the condition of all roller bearings involved in the derailment

- As a check to an uncertain hot box detector reading

- For wayside diagnostics at yard entrances

- During normal car preventive maintenance

Shaker is currently considering manufacture of two models--a very reliable sophisticated model for use at fixed facilities (price estimate $30,000) and a simple model useful for remote location use (price estimate $1200).

Although Shaker Research Corporation now has a working arrangement with the Department of Transportation and the Association of American Railroads, the SRI Team continues to provide assistance as required.

In 1976, the SRI Team arranged for Shaker to present their progress to the Southern Pacific Transportation Company and obtained an offer from the AAR Wheel and Axle Committee to carefully review the product before widespread demonstration to the railroads. In addition, as a result of SRI Team efforts, Abex Corporation Railroad Products Group, a well-established railroad equipment supplier, has offered to aid Shaker with marketing of the product.

A commercial unit of the roller bearing fault detector is expected to be available in 1978.

RESIDUAL STRESS MEASUREMENT IN WHEELS AND RAILS

Detection of residual stress in railroad wheels and rails before hazardous failures occur is essential to prevent train derailments. Each year, broken wheels cause over 100 train accidents and broken rails cause about 800 derailments.

Tensile residual stress can occur when excessive heating in the rims of wheels from friction braking reduces the built-in compressive residual stresses to zero. Continued braking loads the tread in tension, and thermal cracks are generated that can result in explosive-type failures. Many stress-related rail failures also occur. To increase safety and comfort and to reduce operating costs, railroads are using long lengths of welded rail. However, thermal stresses built up in long continuous lengths of rail, constrained from excessive movement by the track, can cause failure. Hot weather induces compressive stresses and cold weather may result in tensile stresses. Failures occur as excessive stress builds up nonuniformally in the rail as a result of nonperfect track conditions. Since these conditions for both wheels and rail cannot always be avoided, effective methods of detecting and measuring excessive stress levels are needed.

The problem of residual stress buildup in railroad track and railcar wheels was brought to the attention of the SRI Team by the Federal Railroad Administration (FRA). The Team was aware that nondestructive Evaluation (NDE) techniques have been used by NASA to measure stress changes in metals, and during a visit to NASA's Marshall Space Flight Center in late 1970, the SRI Team learned of an ultrasonic birefringence technique being developed for aluminum. The technique is based on the fact that the ultrasonic velocity changes as the stress within the material changes. Once the type of material is calibrated, the difference in ultrasonic velocity measurements taken in two directions is a measure of the amount of existing residual stress.

In 1971, the technique was further developed by NASA and was evaluated by both the AAR and the FRA, with the result that NASA provided funding and the AAR provided samples of wheel and rail steel for testing of the device on steel. Promising initial results were obtained and a meeting was held at MSFC for all parties concerned, after which the FRA requested NASA participation and provided funds in 1972 for the inclusion of the MSFC technique within a FRA program to evaluate both destructive and nondestructive methods to measure wheel rim stresses. Ultrasonic velocity measurements were made on several railroad wheels, wheel segments, rail segments, and calibration blocks. Repeated measurements on a given sample were consistent; however, considerable material variability was found. Stress change measurements may be possible by measuring the initial conditions of wheels as a reference for future measurements, but this method is impractical because of constraints of the railroad industry. The results of the work are covered in a NASA report issued in 1974: "Ultrasonic Measurements of Stress in Railroad Wheels and in Long Lengths of Welded Rail" (NASA TMX-64863) and a memo report issued in 1975: "Ultrasonic Measurement of Stress in Metroliner Wheels".[5]

Although the MSFC ultrasonic birefringence technique measurements correlated well with destructive testing measurements, problems of material variability and practical transducer coupling methods for railroad use needed solutions. Consequently, in 1976, MSFC developed the biaxial stress measurement method under the Space Shuttle Program, to accomplish this task. The biaxial method is similar to the birefringence technique but it allows determination of all three orthogonal components of residual stress.

DoT indicated that no single nondestructive evaluation method of determining stress is considered adequate since all are also effected by the amount of cold working the material has experienced. It was suggested that by combining the MSFC technique with another NDE technique, it might be possible to develop an instrument package that would provide the residual stress component exclusively. Since the birefringence technique was effective in determining stress in steel wheels and rail under the FRA program and since the biaxial method is even more practical for infield application, the SRI Team plans to pursue the applicability of the biaxial method with the FRA and the railroads in 1977.

TRACK/TRAIN DYNAMICS

The AAR is administering a national research program to develop data and define options for controlling the dynamic aspects of train operations. The program should lead to improved operating procedures and equipment design. The SRI Team learned of the Track/Train Dynamics Program during the normal course of its activities with the AAR and the railroad industry. The Team recognized the valuable contribution key NASA personnel could make to ensure the success of the program, and informed the Association of American Railroads (AAR) and the Federal Railroad Administration (FRA), of NASA's excellent capabilities in data acquisition and analysis, instrument development, and dynamic modelling used for characterization of the dynamics of complex space vehicle structures. Subsequently, an interagency agreement was signed between NASA and the FRA for the services of Marshall Space Flight Center (MSFC) in support of specific tasks of the overall program.

The objective of the NASA/FRA project is to define an experimentally verified mathematical model of the dynamic properties of an 80-ton open hopper freight car and its ride control trucks, for use in dynamic analysis of curving, hunting, and response to track irregularities via the interaction mechanisms that exist between the car, truck, and track. A corollary objective was to establish the approaches and techniques that may be used in future test efforts to evaluate additional configurations.

In 1974, MSFC issued a contract to Martin Marietta Corporation, Denver Division, a NASA contractor experienced in space vehicle dynamics work, to perform the work under MSFC direction. The program has two major phases: (1) characterization of 70-ton hopper freight car, and (2) characterization of various locomotive trucks.

The work in Phase 1 consisted of a coordinated analytical and test program with the goal of developing experimentally, with analytical correlation, a definition of the dynamic properties of a truck/car system; the results would be suitable for use in dynamic analysis of curving, hunting and response to track irregularities and to the interaction mechanisms that exist between the wheel and the rail. The products of this program are expected to be a procedure for generation of analytical models of the car/truck system, and procedures and techniques for future test efforts by which additional configurations can be evaluated experimentally. The program also includes some participation in road tests under operational conditions to verify the adequacy and applicability of the laboratory test definitions of the car/truck subsystem and the analytical representations of such modeling.

Laboratory tests were performed in three separate test programs. The first test phase was a static test of the truck alone. Six different loading conditions were tested. The second phase was a model vibration test of the car body in a free-free condition, as shown in Figure 10. The third phase was the transfer function test, which was performed on a total car/truck system. The car was mounted on trucks and was excited by motions imposed at the wheels of one truck. The first portion of this test was at low levels of excitation so that the linear model, as a system, may be verified and correlated. Then coupling procedures between the truck and the car body can also be verified at this time. The test was extended to include higher levels of excitation to measure transfer functions in the region which non-linearities occur. The transfer functions, including the non-linearities and the level of excitation required to induce effects of the non-linear elements, were defined in this phase. The highlights of the program are described below:

<u>Analytical Effort</u> - The truck model has been developed and is being correlated with the results of the static tests. The finite element model

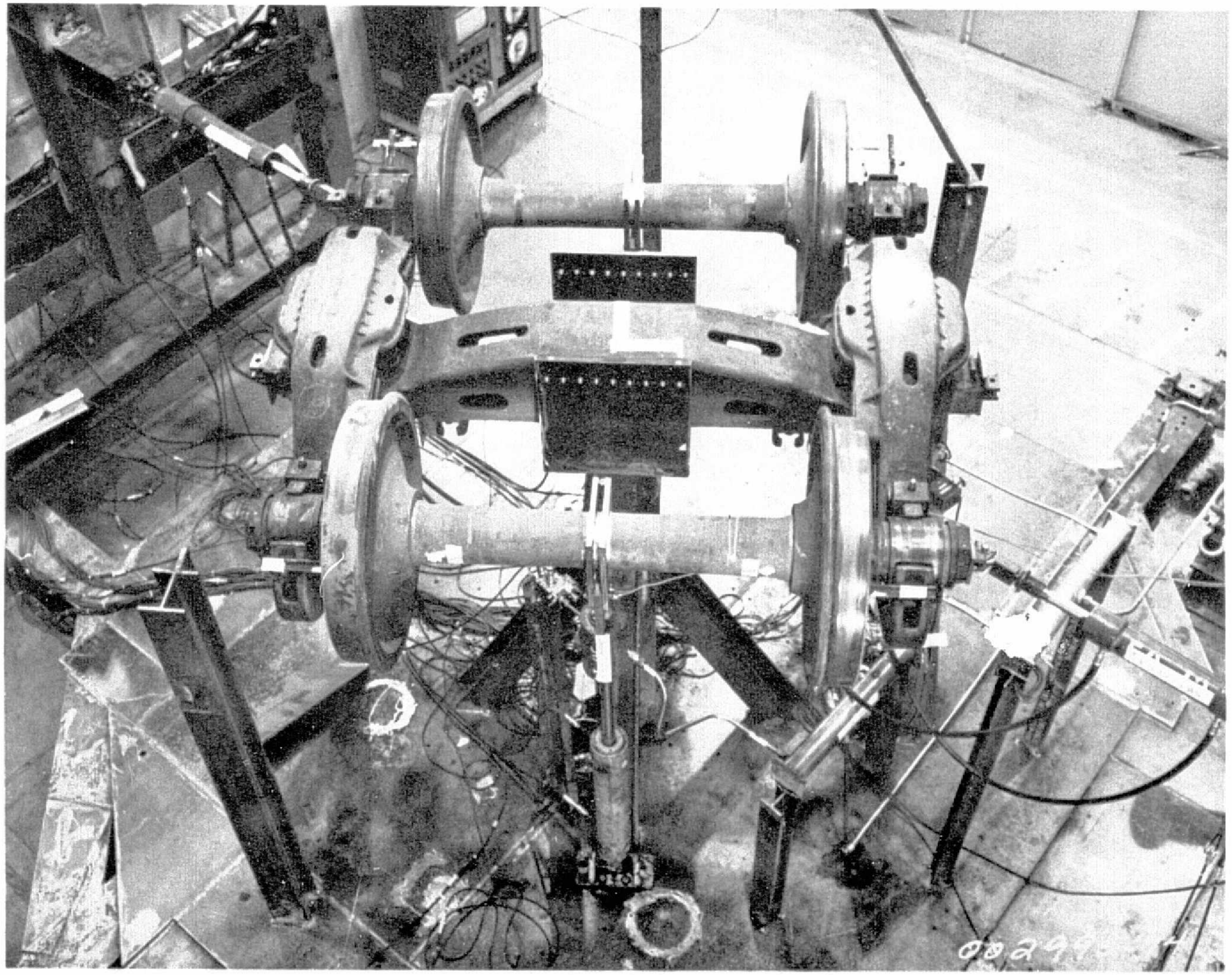

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FIGURE 10 MODAL VIBRATION TEST OF A 70-TON-HOPPER FREIGHT TRUCK of the car body was also developed.

Truck Characterization Tests - The most important part of this test was application of lateral loads to the bolster with various vertical preloads. This condition produces a so-called lozenging or parallelogramming mode responsible for numerous derailments.

Road Test - The final configuration of the laboratory and analytical investigation will be obtained by comparison of results from a road test performed in November 1976 in Nevada on a stretch of a well-controlled track.

The second phase of the Track/Train program, begun in September 1976, involves characterization or determination of dynamic characteristics of several 3-axle locomotive trucks. Some of the locomotives having these trucks, such as SDP-40 and E60 locomotives, have been subjected to numerous derailments in recent years. Certain characteristics of those trucks, appear to generate high lateral forces on the rail and, therefore, force the rail to move laterally until the wheels drop out between the rails, thus causing a derailment. In most cases the derailments occur where the trailing locomotive leaves the track. Because of these numerous derailments, an effort has been undertaken by the railroads and the Federal government, specifically the FRA, to diagnose the problem and try to solve it. As part of this program, NASA/MSFC, in cooperation with Martin Marietta Company, embarked on a program to provide dynamic characteristics of several 3-axle trucks. The tests consist of slowly varying sinusoidal forces applied to the truck in various directions and recording the ensuing motion of various parts of the truck; an example, of a test is shown in Figure 11. The deflection readings produce information on stiffness, friction, and damping characteristics of a truck.

These characteristics, in terms of coefficients, will be used in analytical models to predict the locomotive behavior for various track

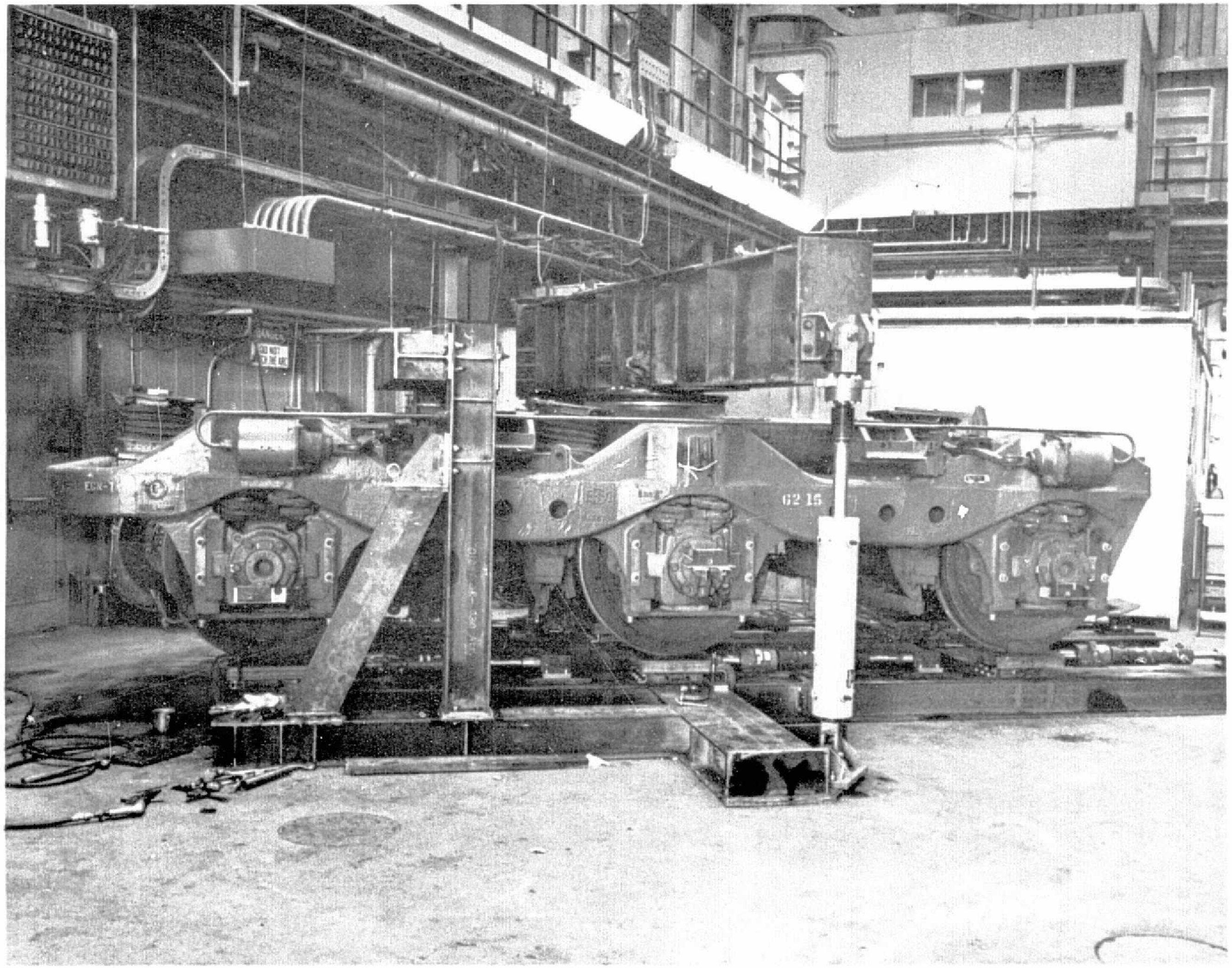

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FIGURE 11 DYNAMIC TEST OF A THREE-AXLE LOCOMOTIVE TRUCK conditions such as entry in and exit out of a curve. The outcome of this program will produce high fidelity test-verified models that should help clarify the derailment problem.

This program is expected to be completed in December 1977. The reports that have been issued to date are listed below:

Date Issued	Report No.	Title
7/1/74	MCR-74-332	Track/Train Dynamics, Test Requirements Document, Pueblo Tests.
7/25/74	MCR-74-313	Track/Train Dynamics, Test Requirements Document, Truck Static Test.
11/1/74	TS-004-OT	Track/Train Dynamics, Test Requirements Document, Track Operational Test.
11/74	TR-1315-74 MCR-74-436	Test Procedure, TR-1315-74, Track/Train Dynamic Analysis, and Test Program, Load-Deflection Testing of Ride Control Truck.
11/74	TR-1315-74	TR-1315-74, Test Report, Track/Train, Dynamic Analysis, and Test Program, Truck Static Test.
5/28/74	TS-002-MS, MCR-72-319	Track/Train Dynamics, Test Requirements Document, Modal Survey.
9/9/74	TS-002-MS	Track/Train Dynamics, Test Procedure, Modal Survey.
1/31/75	TR-002-MS	Track/Train Dynamics, Test Report, Modal Survey.
12/15/74	TS-005-TF	Track/Train Dynamics, Test Requirements Document, Transfer Function Test.
1/6/75	TP-005-TF	Track/Train Dynamics, Test Procedure, Transfer Function Test.
5/30/75	TR-005-TF Vol. I-IV	Track/Train Dynamics, Test Report, Transfer Function Test.

2/76	TR-006-S	TR-006-S, Test Report, Track/Train, Dynamics Analysis, and Test Program, Barber S-2 Static Test.
9/76	MCR-76-475	Technical Report, Comparison of The Non-linear Dynamic Characteristics of Barber S-2 and ASF Ride, Control Freight Trucks.
9/1/76	PTR-001-LST	Track/Train Dynamics and Test Program, Phase C - Locomotive Truck, Characterization Requirements, Document.
11/76	MCR-77-99	Test and Analysis Plan, Track/Train Dynamics, Analysis and, Test Program, Locomotive Truck Characteristics.

TANK CAR THERMAL PROTECTION

The railroad industry has been studying ways to prevent catastrophic failures of tank cars by fire and explosion in postderailment environments. Fire retardant or protective coatings are being evaluated for their ability to maintain 5/8-inch-steel tank cars at 800°F or below for 0.5 to 4 hours during a fire. In 1972, the SRI Team found a potential candidate material in a fiber-loaded intumescent coating developed at Ames Research Center (ARC). The material was submitted to the Association of American Railroads (AAR) and to the Railway Progress Institute (RPI) for evaluation. The ARC material failed to meet the time-temperature specifications under the AAR test. Being familiar with the railroad program, ARC researchers pointed out differences between the AAR/RPI fire test and other laboratory tests for simulating large pool fires. This led the FRA to request assistance from NASA in simulating a full-scale tank car fire and developing a suitable laboratory qualifying test procedure for candidate coatings. A NASA program was funded by the FRA in May, 1973.

NASA scientists at ARC had extensive experience with the development and testing of high-temperature polymers, intumescent coatings, and heat shields for reentry vehicles. Therefore, NASA is providing: (1) analytic descriptions and laboratory simulations of fire environments prevalent in accidents involving fuel-laden tank cars; (2) the fire testing and evaluation of materials, coatings, or systems that may be applicable to the fire protection of tank cars exposed to these environments; and (3) assistance in the conduct by FRA of fire tests of 1/5-scale and full-scale tank cars.

To date, the following work has been completed:

- Fire protection screening tests on more than 50 coatings
- Development and testing of new concepts of fire protection systems suitable for tank car application

- Design, construction, and installation of pool-fire, heat-flux instrumentation for the 1/5-scale and full-scale tank car fire tests at White Sands, New Mexico, and analysis of the data
- Design of a torch-fire test facility
- Partial development of an analytic model of pool and torch fires by a contractor.

A final report is being prepared. ARC is continuing its testing of coatings at the request of FRA.

In June 1976, the SRI Team responded to an FRA request for more NASA assistance for the development of pool and torch fire analytic models. NASA capabilities in this area have been identified at ARC, the Jet Propulsion Laboratory, Lewis Research Center and related to the FRA through SRI Team efforts. It is expected that the FRA will request assistance from one of these centers in early 1977.

MUFFLERS FOR LOCOMOTIVES

All new diesel-powered locomotives manufactured after 31 December 1979 for interstate operation must be equipped with mufflers to meet a locomotive noise emission standard promulgated by the Environmental Protection Agency. In addition, the EPA set less stringent standards for currently operating locomotives, which was effective on 31 December 1976. The regulation was written in accordance with Section 17 of the Noise Control Act of 1972, and it appears in The Federal Register (Vol. 41, No. 9, Title 40; Protection of Environment, Chapter 1, Environmental Protection Agency, Part 201 - Railroad Noise Emission Standards).

Current locomotives can meet the 1977 requirement, but diesel locomotive mufflers will be needed to meet the 1980 requirements. Although mufflers have been tried that will meet the EPA regulation, they are not practical for railroad use. Efficient, compact mufflers will be needed.

Having recognized noise suppression as a significant national problem, the SRI Team had previously identified the Noise Suppressor described in NASA Tech Brief 74-10261. The Noise Suppressor, which is depicted in Figure 12 and 13, consists of multiple bands of acoustically absorbent liners on the inside wall of a duct that forms an acoustic trap that utilizes the reflective elements on the ends to direct sound into the sound-dissipating element in the center. It consists of three cylindrically stacked segments, each of a different porosity and radial thickness out from the inside diameter. It is capable of doubling the noise attenuation of a conventional muffler at peak noise level. Developed at LRC, the patented Noise Suppressor was designed for use in turbofan aircraft engine inlet and exhaust ducts.

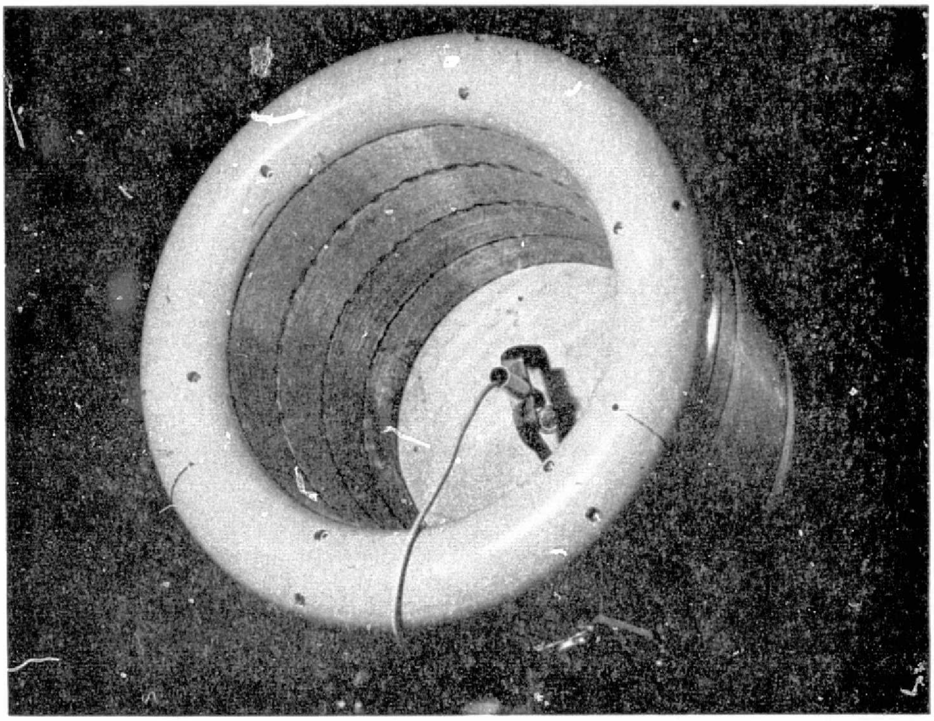

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FIGURE 12 NASA NOISE SUPPRESSOR

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FIGURE 13 NASA NOISE SUPPRESSOR (PICTURED: NASA ADMINISTRATOR DR. JAMES FLETCHER AND INNOVATOR DR. WILLIAM ZORUMSKI)

The SRI Team supplied a report on noise suppression (prepared for the AAR by the Donaldson Company, Inc.) to Dr. William Zorumski of NASA. After studying sound pressure level versus frequency curves of two locomotives, he concluded that the NASA Noise Suppressor, once adapted to the exhaust duct of a locomotive, could meet the 1980 EPA requirements.

After a review of these findings by the AAR and two major locomotive manufacturers, the AAR and one manufacturer requested a meeting with NASA and the SRI Team to discuss the railroad application. A one-day meeting arranged by the SRI Team was held at LRC on 18 August 1976 to determine the applicability of the LRC segmented liner noise suppressor technology to the design of a diesel locomotive exhaust muffler. Representatives of the AAR, three railroads, the Locomotive Production Department of the General Electric Company (GE), and the SRI Team attended, and are shown in Figure 15. Figure 16 shows the discussion group at this meeting. Figure 17 depicts a laboratory prototype of the noise suppressor.

FIGURE 14 ATTENDEES OF THE LOCOMOTIVE MUFFLER MEETING

Left to right: W. Zorumski (NASA), K. Hawthorne (AAR), E. Harley (Con Rail), C. Furber (AAR), B. Rust (Santa Fe), C. Muelder (Burlington Northern), J. Wilhelm (SRI), E. Martin (GE).

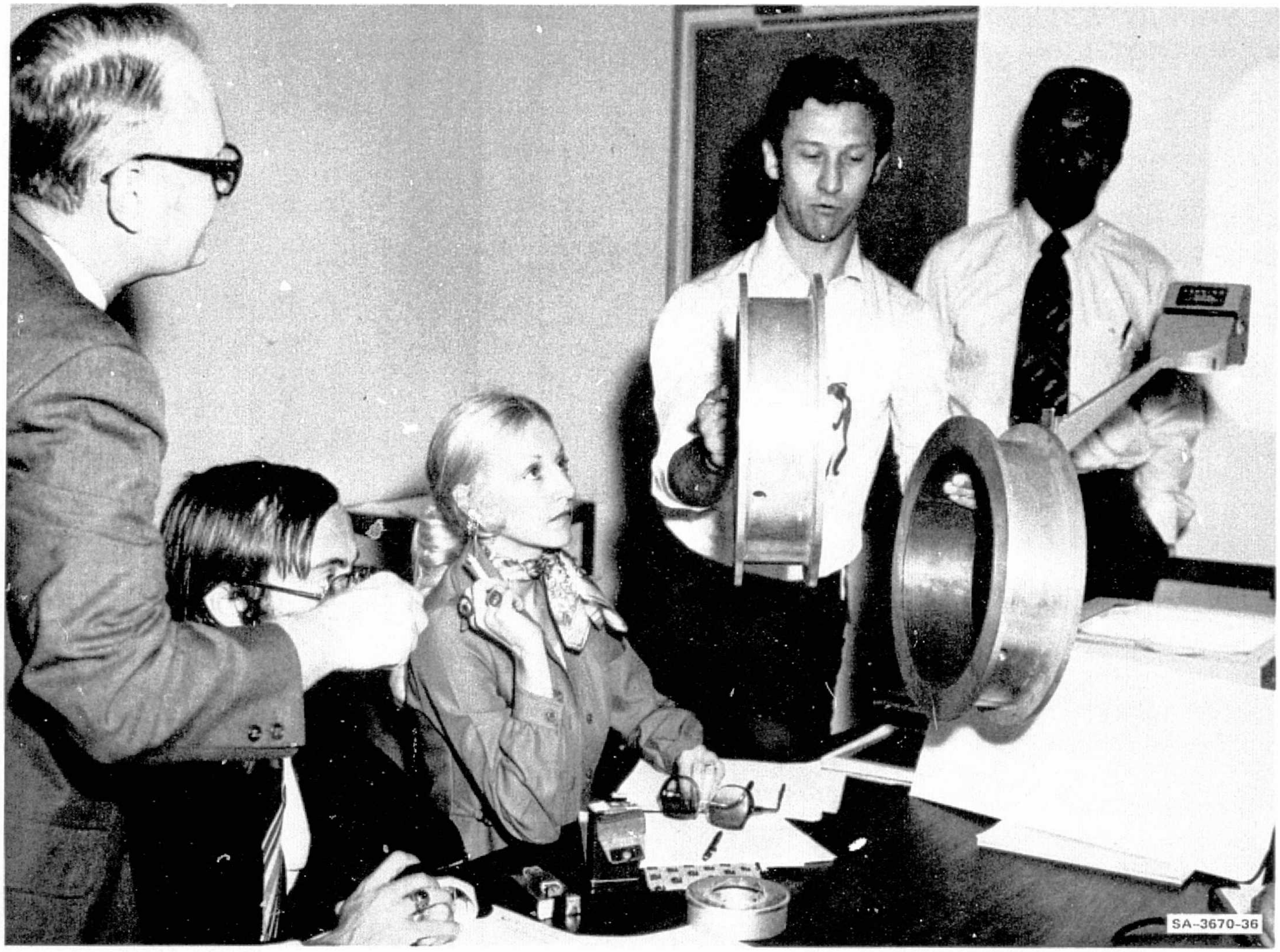

FIGURE 15 DEMONSTRATION OF LRC SEGMENTED LINER TECHNOLOGY SHOWN AT LOCOMOTIVE MUFFLER MEETING

Pictured left to right: E. Harley (Con Rail), K. Hawthorne (AAR), B. Rust (AT & Santa Fe), W. Zorumski (LRC), L. Clark (LRC).

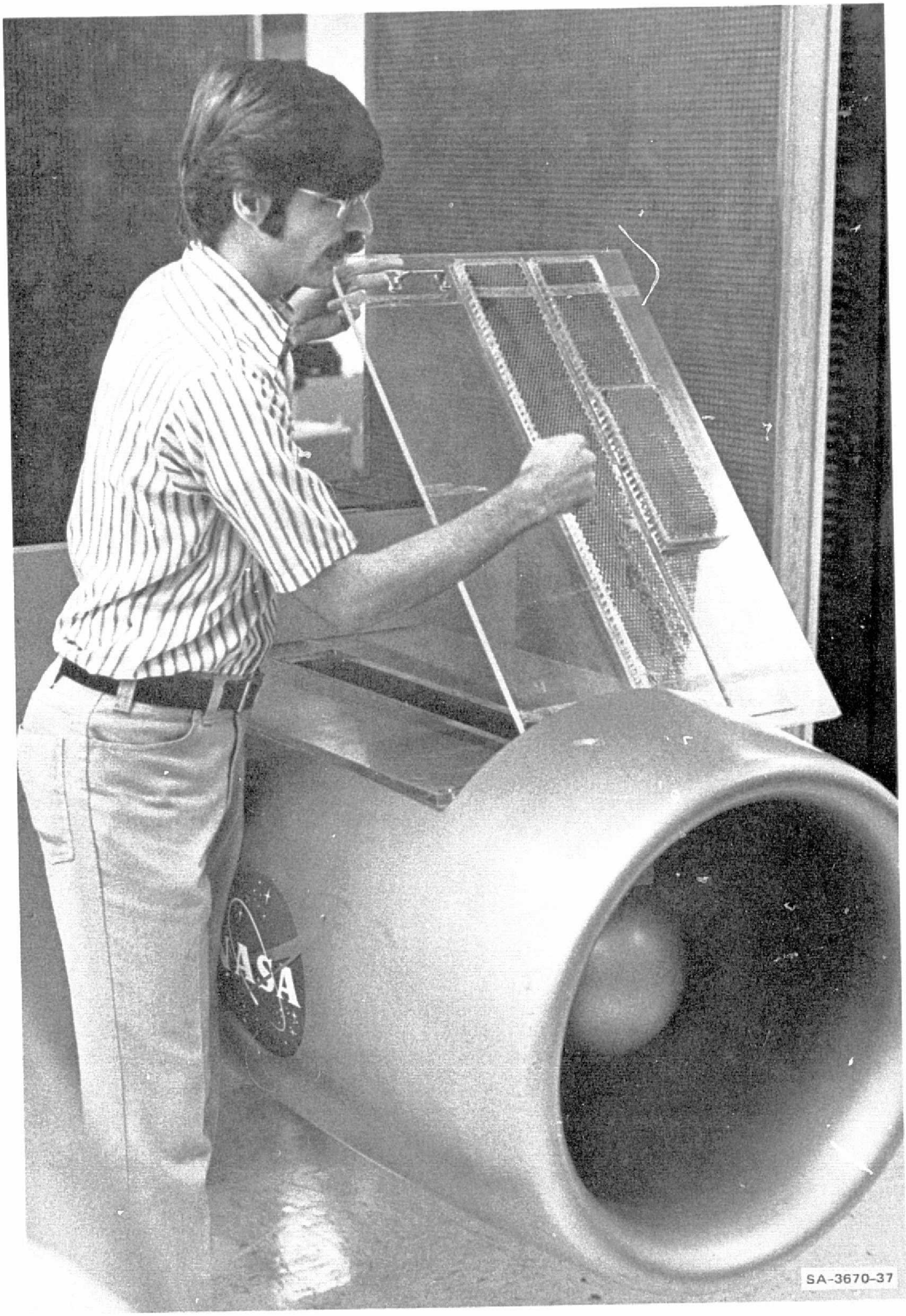

FIGURE 16 LABORATORY PROTOTYPE OF LRC SEGMENTED LINER NOISE SUPPRESSOR: DEMONSTRATION FOR THE U.S. RAILROAD INDUSTRY

PRELIMINARY RAILROAD PROBLEMS

During this reporting period, the SRI Team visited ten railroads, a railroad supplier, the Association of American Railroads, the Federal Railroad Administration, and DoT's Transportation Systems Center for a thorough survey of railroad industry problems. This allowed the Team to identify the industry's most important problems, the current state of the art of existing technology, and current railroad research programs.

The industry-wide problems and needs identified as a result of these visits included:

- Reliable, maintainable electronic components for locomotives
- Durable locomotive light bulbs
- Continuous monitoring of diesel engine diagnostics
- Traction motor overheating detector
- Locomotive muffler*
- Reduced diesel exhaust pollution
- Improved locomotive traction (wheel/rail adhesion)
- Future propulsion systems
- Preprogrammed automatic train operation
- Reliable speed recorders+
- Human factors in engineering for locomotive and caboose
- Human waste disposal system+
- Long-life, large-temperature-variation lubricants for auxiliary equipment
- Reduced wear on truck center plate and snubbers by improved design, material and/or lubricants
- Stronger steel for couplers
- More durable fasteners
- Extreme temperature range elastomeric material for dampening car body roll
- Corrosion protection for hopper cars*

- Long life paint
- Durable boxcar door rollers and locks
- Self-aligning coupler
- Roller-bearing cap screw that remains tight in service
- Computer program for wheel structure design by stress expectations
- Improved brake shoes *
- More durable brake hose material
- Brake-line air-leak detector +
- Automatic brake-line coupling system
- Control system to adjust braking to railcar weight
- Improved braking system
- In-motion cracked wheel detector
- Automatic thin wheel flange detector
- Bearing surface-hardness nondestructive tester
- Experimental equipment for rail fatigue stress and metal flow measurement
- Instrumentation for measuring mechanical forces on cars
- Telemetry for use within trains *
- Reduced retarder bar noise during humping
- Reduced wheel/rail squeal and coupler noise
- Technology to reduce automobile/train collisions at highway crossings
- Low-temperature flashlight batteries
- Solar cells for yard switch stands and cabooses +
- Steel flow detector
- A solid bearing lubricant that will not dry or wash off
- Detector for stuck brake shoes
- Retarders for good speed control
- Automatic tie inspection device
- More communication channels in a fixed frequency band

- Noncontact rail gage measurement device
- Train-to-train detector to avoid collisions
- Locomotive air filters
- Large-screen computer simulation visual display
- Improved reliability of microwave communications
- Integration of communications and data processing equipment
- Locomotive research simulator definition
- Crashworthiness design
- More durable track
- Improved tank car fixtures
- Wheel and rail profilometer *
- Test management techniques
- Materials and structures technology *
- ACI scanner improvement
- Stability devices to stop car rock and roll and truck hunting
- Longer-life or less expensive crossties
- Locomotive data recorder
- Man-machine interface engineering for locomotives

A problem survey to define the specific need, including specifications, and/or a technology survey to identify associated NASA technology was conducted on 15 of these preliminary problems. Details of action and progress on these problems identified by an asterick (*) above are included elsewhere in this report. As a result of problem surveys, commercially available technology was identified to already exist for those problems denoted above by a cross (+).

Technology searches have yet to identify applicable NASA technology for improved tank car fixtures and for man-machine interface engineering for locomotives.

A problem statement will be prepared in early 1977 to elicit NASA suggestions of technology to reduce automobile/train collisions at highway crossings.

Significant effort was not expended on many of the other problems listed due to apparent economic or political considerations that override a technical solution. There are, however, several problems on the list that the SRI Team expects to investigate in 1977.

IV RAPID-TRANSIT INDUSTRY PROBLEMS

FIRE-RESISTANT MATERIALS

Fire safety is the number one concern of the mass transportation industry because all mass transit vehicles are susceptible to fire damage of some type, and the possibility of a catastrophe is high due to the volume of people transported in such vehicles. Newer vehicles are especially susceptible to fire because increasing quantities of plastics are used in their construction.

For increased passenger safety in case of a fire in a rapid transit car, especially in the confines of a tunnel, construction materials need to be more fire-resistant than those now used. Improved materials are sought for thermal and acoustic insulation, wall and ceiling panels, floor covering and carpeting, seat cushions, and seat covers.

In addition to the cars, the electric cables in subway tunnels have also been involved in fires. With the loss of power, the blinding smoke and toxic gas evolved in a fire in such a confined area can be a greater threat to passengers than the fire itself. The immediate problem could be eliminated if a smokeless coating or covering, which did not produce toxic gases, could be applied to existing signal, communication and traction power cables in tunnels. However, the development of new electrical insulation and jacketing materials that have minimal smoke and toxic gas emissions and ignition characteristics is expected to be more feasible.

The problem was initially related to the SRI Team by DoT's Transportation Systems Center and the Transit Development Corporation.* In addition, the Urban Mass Transportation Administration (UMTA) and most transit authorities want economical fire-resistant materials for use in their vehicles. In addition to use on rapid transit cars, the

* Now merged with the American Public Transit Association.

increased use of fire resistant materials on other passenger carrying vehicles such as buses, ships, trains, and recreation vehicles would increase safety in travel. For example, government regulations are becoming more stringent regarding recreation vehicle fire safety.

The tragic Appollo 6 Fire on 27 September 1967, which took the lives of astronauts Grissom, White, and Chaffee, motivated NASA to focus on the development of fire-resistant nonmetallic materials. As a result, with the aid of almost every NASA center, NASA has developed or funded the development of several nonmetallic materials and formulations that meet the flammability and toxicity requirements for spacecraft use. These materials are now occasionally used in the public and private sectors in cases where weight and flammability considerations remain of high importance and cost is less of a consideration (such as in aircraft).

The cost of these materials mitigates against their high-volume use in the public and/or private sector. The high-volume usage projected for rapid transit applications alone, for example, requires a significantly more inexpensive material if commercialization is to occur.

As a result of the SRI Team's dissemination of a problem statement* defining the transit industry's requirements and needs, Ames Research Center (ARC) initiated a study in March 1975, sponsored by NASA TU, to determine what existing advanced aerospace materials may be used in mass transit vehicles for increased fire safety. This study was based on materials considerations primarily, and economic considerations were of secondary importance. ARC utilized the services of Rohr Industries, Inc., a major rapid transit car manufacturer, for performance of many tasks.

The final report of the ARC/Rohr Industries, Inc., "Study of Thermal Structural Composites" for rapid transit cars is now available as NASA

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* The problem statement is included in Appendix B.

CR 137947. Two high-performance organic polymer-based foams developed by ARC scientists for spacecraft fire safety--polybenzimidazole and polyquinoxaline--were selected for screening as cores for fire-resistant aluminum face sheet sandwich panels. The applications of interest were wall, floor, and ceiling panels for rapid transit cars; the key evaluation criterion was prevention of penetration by external fire. It was concluded that a polyquinoxaline/Nomex core combination was the most promising because of low flammability, resistance to burn through, low emission of smoke and fumes, retention of structural capability after fire exposure, lighter weight, and crash resistance. However, the study concluded that the developmental materials are currently too expensive to be considered for actual rapid transit car application. Polybenzimidazole core panels cost about 13 times as much as plywood (the material now commonly used), and polyquinoxaline costs about 25 times that of plywood.

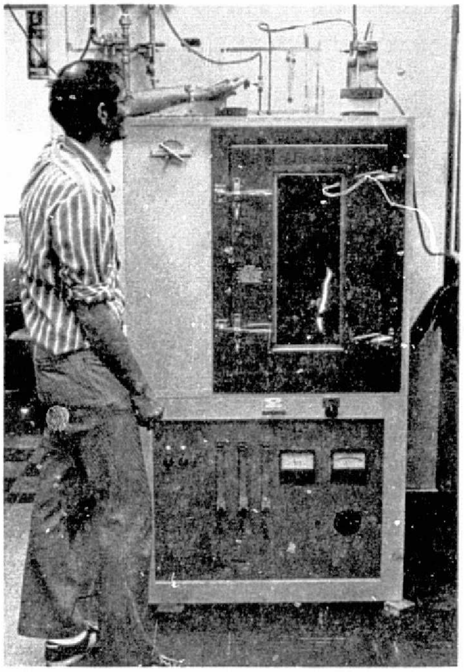
In addition, as a result of the NASA problem statement, the SRI Team learned of some highly interesting results of new fire-resistant polymeric material developments at the Jet Propulsion Laboratory (JPL). JPL scientists are making polymeric materials fire resistant by the addition of substantial quantities (of the order of 50% or more) of fillers and additives such as carbonates, hydrates, oxalates, oxides, and nitrogen compounds. When materials made in this way are exposed to flame or high temperature, the filler components generate large amounts of non-toxic gases (such as water and carbon dioxide) to dilute the flammable and/or toxic combustion products so as to inhibit flame spread and flash-over. They will also promote the formation of char or solid residue, giving enhanced thermal protection. In addition, the materials cost little more than currently used polymers in transit vehicles.

Filled polymers have been developed in the past, but they generally have poor physical properties. JPL's unique experience with highly filled polymers for solid rocket propellants, however, has allowed the preparation of systems with high filler content and yet tailored physical properties. The JPL scientists use surfactants and bimodal particle size distributions of fillers to increase effective volume packing of fillers and to minimize adverse effects of high volumetric loading.

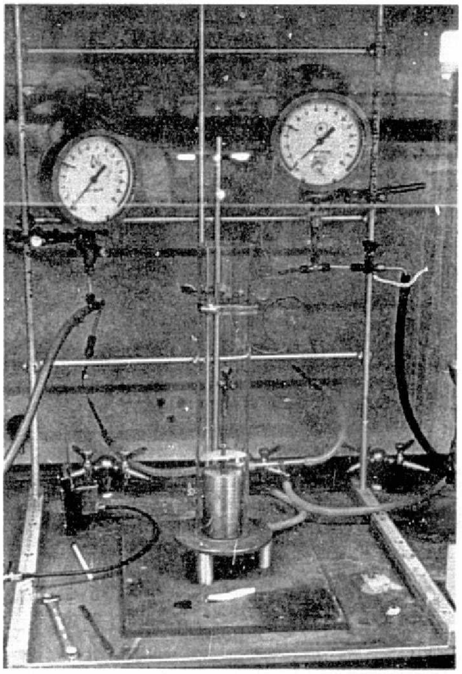
Both the SRI Team and the DoT's Transportation Systems Center reviewed the initial JPL results and saw great promise for the utilization of these materials. Consequently, NASA TU funded a development program to allow the JPL researchers to complete their evaluation of the fire, smoke, and toxic off-gasing properties as well as the physical properties of the currently developed materials, and to more vigorously pursue the theory underlying the choice of filler material.

The project began in August 1975, and since then scientists at JPL have installed an NBS Smoke Chamber and a Limiting Oxygen Index Testing Setup, which are shown in Figure 17. They are currently testing the smoke and flammability characteristics of various combinations of in inorganic fillers and base polymers. Results obtained through September 1976 are detailed in the JPL progress report "Fire and Smoke Retardant Materials for Mass Transit Vehicles."[6] Tests indicated that the best smoke retardants are $Na_2Sio_3 \cdot 9H_2O$ and $Mg(SO_4) \cdot 7H_2O$, and $Mg(OH)_2 \cdot CaCO_2$ in a polyurethane also shows much promise. When it is confirmed that an elastomer can be prepared that is fire resistant and generates very little smoke, further work will be done to improve mechanical properties, primarily by methods developed in past solid propellant work.

When this program is determined suitable for application, the JPL scientists will work on the adaptation of the materials from the JPL process to specific transit industry components. The first development will be an improved fire-resistant, low smoke-emitting cable insulation



(a) NBS SMOKE CHAMBER



(b) LIMITING OXYGEN INDEX TEST APPARATUS

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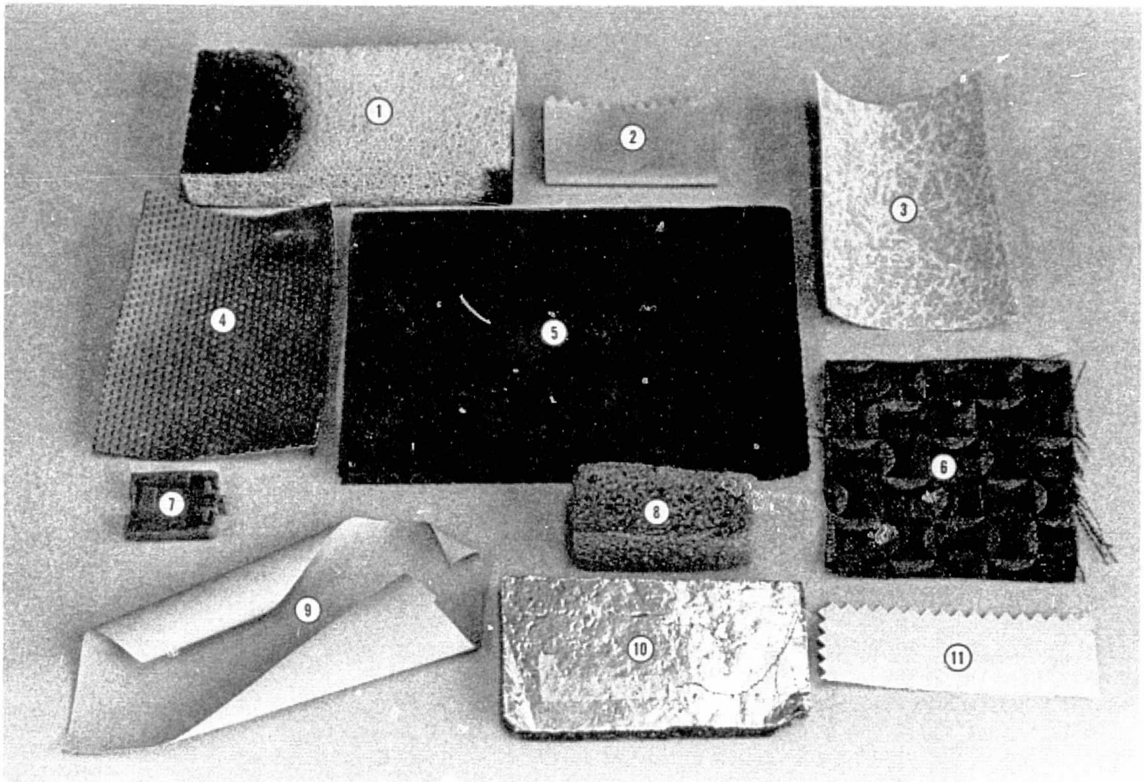
FIGURE 17 JPL FIRE AND SMOKE TESTING APPARATUS and jacket. This objective, if achieved, is expected to have great impact in the mass transportation industry.

JPL researchers are also attempting to develop rigid fire-resistant polymers for NASA aircraft interiors. The same materials might also be used on surface vehicles.

In addition to the work at ARC and JPL, the Johnson Space Center's program of the development, application, and testing of cost-efficient combinations of aerospace fire-resistant materials (shown in Figure 18) with conventional materials for aircraft interiors appears most promising for potential surface vehicle application. New materials have been developed in aerospace research projects and have been used successfully in the Apollo and Skylab programs and planned for use aboard Space Shuttle. Some of these and other advanced polymeric materials are being adapted to aircraft requirements to yield economically priced, fire-resistant, low smoke, thermally stable, and commercially available aircraft cabin materials that posses comparable physical properties to those currently used. Data on component, full-scale, and actual flight tests are currently being obtained to verify the applicability of these materials for use in aircraft interiors.

NASA's material selection criteria for the program are: for flammability, a minimum limiting oxygen index of 30 and the ability to pass the FAA flammability tests; for smoke density, a maximum specific optical density of 50 in the NBS Smoke Chamber; and for toxicity, material thermal stability to 390°F minimum, as any gases about 390°F are lethal when inhaled. In addition, physical property standards and associated requirements of durability, cleanability, weight, aesthetics, availability, ease of fabrication, and ease of installation must be met. Cost is the most important criteria for commercial aircraft applications. The cost of the fabricated materials cannot be more than 15-20% higher than the conventional materials they are intended to replace.



1. Mobay foam 115014-6 treated with $NH_4H_2PO_4$ and overcoated with Fluorel L3203-36
2. Blue Fluorel with Kel-F FX 703 coating on Nomex fabric
3. Kynar (decorative style)
4. Blue Fluorel L3203-36 on fiberglass
5. FX resin impregnated fiberglass skins on a normal phenolic impregnated Nomex honeycomb core
6. Wood Weaval Blend
7. Fluorel L3203-6
8. Resiliant polyimide foam
9. Nylon with Kel-F 2401 B
10. Aluminum foil on rigid polyimide foam
11. Fiberglass with white Fluorel L3203-36 with blue pigment and Kel-F X33 on top

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FIGURE 18 FIRE-RESISTANT MATERIAL USED IN THE JSC AIRCRAFT PROGRAM

The emphasis on cost in combination with the other selection criteria makes this a unique program that will have very practical and usable results.

The goal of the NASA JSC program is the development of aircraft materials that will meet the selection criteria for the following applications: high resilient open cell foams for seat cushions, rigid foam for wall and floor panels, thermal and acoustical insulation, fiberglass or other laminates with decorative and protective coatings, formable thermoplastic and thermosetting polymeric materials, windows, sandwich panels, decorative coated fabrics, and insulation bagging material.

Results to date include the development of a fire-resistant, highly resilient, open cell polyimide foam with a finished cost of approximately $0.50 per board foot. The basic polymer will be reformulated for applications as a rigid foam for wall and floor panels, a thermal-acoustical insulation material, a moldable resin, and a fabric coating. For 1977, the development of materials for use as thermal acoustical bagging, laminates with decorative and protective coatings, decorative coated fabrics, and windows will be pursued.

The SRI Team will review the results of this program as they occur and will initiate the transfer of applicable technology.

A SYSTEMS ASSURANCE PROGRAM FOR THE RAPID TRANSIT INDUSTRY

To meet the growing need for urban public transportation in the United States, significant construction and expansion of rail rapid transit systems is planned. Three transit authorities are expanding, one new transit property was recently completed, three new transit systems are under construction, one new transit system is in design, and many more cities have been considering construction of a fixed rail system.

An increased use of new technology such as automation is occurring in the new and expanding fixed guideway rapid transit systems with the addition of such subsystems as automatic train control. The addition of automation to an already complex transit system can lead to more frequent failures, increased maintenance requirements, and less system availability. To overcome these problems, the elements of systems assurance (e.g., quality assurance, reliability, maintainability, system safety and security, and system life cycle cost) must be designed and integrated into the overall transit system. To achieve this, improved engineering systems assurance technology and management methodologies for the transit industry are needed.

Subsystems of the overall transit system include vehicles, automatic train control, auxiliary systems, rail and right-of-way, civil structures, operational procedures, personnel and management. Therefore, system design, test, evaluation, and management methodologies and experience are needed for the complicated process of new system planning, specification, source selection, contract management, systems integration, first article testing, and system tests.

Most of today's systems assurance technology was originated and developed by the aerospace and defense industry. NASA's expertise in the application and integration of systems assurance led to the successful completion of many large complex projects such as the Apollo Program. Therefore, the SRI Team initiated an effort designed for the application of NASA's systems assurance and management technology to the rail rapid transit industry.

The SRI Team was initially exposed to the problem in Spring 1974 through general interest in NASA reliability techniques by several rapid transit properties and by a specific request made by the Transit Development Corporation* for details on NASA failsafe design techniques. The problem survey began with the collection and review of several important reports containing recommendations to DoT and the transit industry. Discussions with representatives of the Urban Mass Transportation Administration, DoT's Transportation Systems Center, and the Transit Development Corporation broadened user interaction in the problem survey.

An SRI problem statement+ issued in November 1974 and a December 1974 Executive Summary ≠ of the problem with general suggestions of applicable NASA technology drew considerable response. Specific suggestions were received from seven NASA centers and two NASA contractors. The interest and approach displayed by Kennedy Space Center (KSC) engineers showed the greatest promise for transit industry application. It appeared that KSC project management and systems engineering experience and techniques (such as a Risk Management System) could be assembled in a project for use by the U.S. transit industry. The techniques could include those used successfully by NASA for the design, construction, and operation of large, complex facilities and the integration, test, and launch of highly reliable current state-of-the-art hardware.

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* Now merged with the American Public Transit Association.

\+ The problem statement is included in Appendix D.

≠ The Executive Summary is also included in Appendix D.

A Project Management Control System (PMCS), an outgrowth of the Risk Management System, could be a carefully designed series of control processes for use in implementation of a rapid transit project. As such, it would enable project management to: (1) exert comprehensive, timely, effective, and systematic controls over all project activities; (2) assure on-time delivery of the completed project; and (3) assure the reasonable attainment, in terms of the completed project's facilities and equipment, of goals and standards (e.g., quality, safety, assurance, reliability, maintainability, and costs) established for the project.

Evaluations of the KSC techniques by the Urban Mass Transportation Administration, the Transit Development Corporation, DoT's Transportation Systems Center, several transit properties, and a transit industry supplier confirmed the SRI Team's belief that the techniques could be successfully applied to a Project Management Control System for use by transit authority management.

After a thorough investigation of user agency transfer options, the SRI Team directed its transfer efforts toward new transit properties, because this approach offered a more direct utilization of the NASA techniques by the transit industry. The NASA techniques were introduced to the Metropolitan Dade County Office of Transportation Coordination Administration in Miami, Florida, in meetings arranged by the SRI Team in October and December 1975.

As a result of these SRI Team efforts, UMTA and NASA plan to fund a technology utilization project at KSC for the development of a rapid transit Project Management Control System. The Metropolitan Dade County office in Miami, Florida, would like to work with KSC engineers to adapt and utilize the system during the design, construction, and operation of a rail rapid transit system in a project currently under way for the county. The methodology and results could be documented in a format that can be applied by other cities in the United States as rapid transit construction programs are instituted and carried out.

In a meeting at KSC on 10 September 1976, the KSC Center Director decided that the NASA-KSC technology requested by Dade County would require the transfer of high level NASA management techniques and systems. An interagency agreement has been prepared by UMTA, but it requires a statement of work agreed on by Metropolitan Dade County and KSC. A project development plan has been prepared to define the scope, the approaches, and the products of the technology transfer project, as a basis for the NASA-UMTA Interagency Agreement, which furnishes funds and authority for this project. A draft PMCS Project Development Plan was prepared at KSC for signing. The KSC Center Director has approved the project, but final agreement must await management functions currently under way, such as allocation of manpower. The technology transfer project is expected to start in 1977.

KSC has already provided some assistance to Dade County. In November 1976, Kaiser Transit Group (Architectural and Engineering Consultants to Dade County) staff visited KSC and related some problems in establishing management control systems for the large design and construction project. KSC responded initially with several NASA documents (including plans for general safety, facility management, and configuration management, and offered additional assistance, if desired, once the documents are reviewed.

The SRI Team also worked closely with the Jet Propulsion Laboratory on a successful effort toward application of NASA quality assurance technology for the transit industry. This work was part of a study funded by the DoT's Transportation Systems Center for UMTA by an agreement with NASA and implemented under a NASA contract (Contract NAS-7-100). The overall objective was to recommend to UMTA a viable quality assurance program for the urban mass transit industry, and a management approach to ensure compliance with the program. Specific objectives included:

- Recommending, for UMTA use, a set of quality assurance guidelines to be imposed on transit authorities, and a management approach to ensure compliance with these guidelines.

- Recommending a management approach to be used by the transit authorities (properties) for assuring compliance with the above guidelines.

- Recommending quality assurance guidelines to be imposed by properties and UMTA for procurement of hardware and systems.

The recommended program and management approaches are based on the concept that a quality assurance program is required to protect the interests of the transportation user and producer community from errors or misjudgement in technical and procurement activities. To the extent that the risks to the user interests are economically controllable through activities conducted before grant-funded transit elements are put into operation, appropriate quality assurance activities were identified. In addition, interfaces with quality assurance were considered--for example, design and development, systems engineering, reliability, safety, and test.

The JPL project began in March 1975 and was completed in August 1976; the work resulted in two reports: "Summary of Development and Recommendations for a Quality Assurance Program for the Procurement and Manufacture of Urban Mass Transit Operating Equipment and Systems" (Final Report JPL UMTA-QA Task, 5040-35) and "Quality Assurance Program Guidelines for Application to and use by Manufacturers of Rail/Guideway Vehicles, Buses, Automatic Train Control Systems, and Their Major Subsystems" (JPL UMTA-QA Task, 5040-34).

To date, UMTA and TSC have not responded with their evaluation of the JPL recommendations.

Both the KSC Project Management Control System and the JPL quality assurance methodologies will be complementary toward a complete transfer of NASA systems assurance technology for the transit industry. The products of these efforts could be used by management and engineering personnel of the Urban Mass Transportation Administration, individual transit authorities, project sponsors, state and local regulatory bodies, and transit industry suppliers in applying the system assurance methodologies during the new construction or extension of a rapid transit system.

V WATERWAYS PROBLEMS

GENERAL

During the past year the SRI Team expanded its activities to include investigation of problems in maritime and inland waterways systems. Initial visits to the following federal agencies were made to identify current problems of high priority:

- Maritime Administration, DoC
- NOAA, DoC
- U.S. Army Corps of Engineers, DoD
- U.S. Coast Guard, DoT
- Materials Transportation Bureau, DoT
- Office of Deepwater Ports, DoT

On the basis of these visits the SRI Team additionally contacted 9 national associations, 4 port authorities, 7 shipyards, and 11 cargo carriers. Subsequently, newsletters were sent to 75 key individuals in these public and private organizations to inform them of the work in progress during the year and to request updating of the problem identification list. Ninety problems were considered as having potential for NASA technology application. The following are considered typical.

PRELIMINARY WATERWAYS PROBLEMS

Pipeline Leak Detection

Several deepwater ports are scheduled for construction, typically 25 miles offshore, to receive crude oil from the ultralarge crude carriers that are too large to enter most existing harbors. The oil will be pumped via submerged, buried pipe to transmission lines onshore. Because large leaks or pipe rupture could result in disastrous pollution, the USCG has been conducting a search for optimal means of detecting and locating flaws and leaks in these petroleum pipeline systems. A problem statement sent to NASA Centers by the SRI Team received several responses, primarily suggesting the use of double-walled pipe construction. Two solutions were proposed for the problem of underwater hydrocarbon detection: an adaptation of a semiconductor smoke detector being developed by NASA at MIT, and a modification of the Taguchi sensor, an inexpensive, commercially available hydrocarbon sniffer, for underwater use by MSFC personnel familiar with its operational characteristics. However, since port construction will soon begin, the USCG determined that there would be insufficient time within its schedule to draft pollution protection regulations to modify these suggestions for its use. Thus, no further work is expected on this problem.

Shipboard Medical Systems

The provision of emergency medical care to seamen is subject to a similar constraint that NASA encounters in attempting to provide medical care to flight crews on extended missions: no medical doctor is readily available for on-site care. Thus, NASA's experience, particularly in the Skylab program, may have maritime application. However, the relative cost of providing such care is an important factor. At present, medical provisions include manditory medical kits on large vessels and the care system coordinated by the USCG, whereby ships with doctors aboard are advised of the emergency needs of crews on vessels within their vicinity. Even with the onset of ocean satellite communication providing a means for consulting doctors on-shore, shipping companies may see no need for changing these current practices.

The Maritime Administration (MarAd) is currently assessing the priority of this problem and should determine soon the extent to which it will support R&D in this area. If a program is initiated, the SRI Team will again contact JSC to ensure that MarAd benefits from NASA experience in developing a full medical treatment system.

Firefighting Module

MarAd advised the SRI Team of its intention to determine the feasibility of developing modular fire fighting equipment that can be delivered by helicopter to assist vessels on fire. This equipment need was identified during MarAd's program for coordination of regional firefighting capabilities.

In turn, the SRI Team informed MarAd of the MSFC-USCG joint program to have a prototype of a MSFC-designed unit produced for testing in mid-1977. MarAd determined that this unit should meet its proposed specifications and thus will await the test results before proceeding further.

Respiratory Air System

The USCG requires a reliable self-contained system that will provide respiratory air and body cooling for at least 2 hours. Such systems are needed for emergency response to hazardous materials spills producing toxic and/or oxygen-deficient atmospheres. In addition to being reliable, the unit must be easy to maintain and the logistical support requirements must be minimal. Units have been developed that will meet the 2-hour requirement (e.g., cryogenic air systems); however, they are not completely reliable and require excessive logistics.

Currently the USCG protective garment is made of butyl rubber, which limits effective personnel activity in hot weather because of its weight and thermal insulation. The SRI Team supplied the USCG with data on the energy costs for various activities so that it might accurately estimate its body cooling requirements; the data were taken from NASA's Bioastronautics Data Book, (SP3006). In addition, the Team forwarded to the USCG full information on the NASA-developed body cooling system marketed by the Aerotherm Division of Acurex, Inc. The USCG is interested in this unit and is including it in a proposed technical approach being submitted in spring of 1977. A decision of whether to continue this project to develop protective clothing for toxic material cleanup should be made in early June, at which time the SRI Team will determine whether further assistance is required.

Electrical Materials

The National Electric Code is about to approve many new types of cables that incorporate new insulation and jacket materials. MarAd and the USCG anticipate being deluged with requests from shipbuilders to use these new materials and need information on their smoke and flammability properties. In response to this need the SRI Team has supplied the MarAd office responsible for this problem with a handbook compiled at JSC entitled "Nonmetallic Materials Design Guidelines and Test Data". No immediate development work by these agencies is anticipated, because they are aware that the U.S. Navy is conducting research as a result of the finding that current mil spec cable can sustain fires, and they will probably await the results of this work.

Another concern is the high cost of electrical cable installation. To assist in this problem, the SRI Team has furnished MarAd with details on flat conductor cable supplied by MSFC.

C-8

LNG Dispersion

The potential danger represented by an LNG spill and its vapor cloud is well recognized. What is not well understood are the mechanics of the cloud's dispersion and the means of minimizing a vapor cloud formation. The American Gas Association approached the SRI Team with its need to have wind tunnel tests conducted on cloud dispersion in the presence of varying geometry barriers and an atmospheric temperature inversion layer. After consulting with ARC and LeRC, the Team determined that NASA centers were already in direct communication with the AGA and thus Team assistance was not needed to facilitate the transfer of pertinent NASA technology.

Ship and Ice Detection

A NASA-developed S-band short-pulse radar unit used by the USCG for remote profiling of ice has the potential for extending the Great Lakes shipping season when used in conjunction with airborne side-looking radar capable of detecting ice, ships, and pollution targets. Real aperture radar has been used aboard a C-130, an aircraft capable of transporting the required 20-ft antenna, but for the newer executive-size jets ordered by the USCG, synthetic aperture is needed. The SRI Team informed the USCG of JPL experience with synthetic aperture. However, USCG operations require high-resolution, real time data at a cost comparable to data supplied by real aperture radar. The SRI Team was advised that because of the current trade-off between cost and resolution, a unit capable of meeting the USCG requirements will probably not be available for several years, thus, the Team decided to curtail further effort on this preliminary problem.

Ship Identification

With respect to its new responsibility to limit the catch of foreign fishermen within the extended 200-mile offshore limit of U.S. authority, the USCG identified two problem areas for the SRI Team. The first need was for a device capable of providing the required signals day or night and in all weather conditions to meet the recent laws requiring licensed foreign fishing vessels to carry onboard a transponder or other suitable identification and positioning unit. The SRI Team determined that the transponder developed by GSFC and used by NOAA seemed to meet the required specifications and that NASA, NOAA, and the USCG were at that time jointly discussing this device. Consequently, no further Team involvement seemed appropriate.

The second request was for an air-cooled, charge-coupled-device, activated television system. Such a unit would have great promise as a light-weight, reliable, and small-volume airborne system for ship identification and activity investigation at night of vessels detected not carrying a transponder. The SRI Team determined that NASA solid state imagery projects were not considering artificial light sources and that CCD's limited to solar infrared detection would require a ship to remain still for 10 minutes in order to produce a suitable image. To extend CCD operation into the thermal infrared (up to 5 micrometers) and to produce operational devices, the miliary would require at least 2 years of development work. Consequently, the SRI Team has discontinued effort on this preliminary problem.

Crew Isolation

A recent study reported that crew error is responsible for 80% of marine casualties. Among major contributing factors were isolation and boredom, attributes associated with job assignments on new larger, more automated vessels. The TU office at ARC supplied the SRI Team with NASA studies designed to investigate these phenomena and to develop methods to combat their debilitating effects. This material has been forwar'ed to the National Maritime Research Center which is completing a report identifying and describing 15 problem areas of crew behavior. No further Team effort is expected, until MarAd determines what action to take on the basis of the NMRC report.

Wave Height/Spectra Measurement

Ships in stormy weather need more accurate immediate information on the sea conditions in their vicinity to determine the necessity of course changes to maintain vessel safety. The SRI Team informed MarAd of NASA gyro-stabilized platforms which are capable of providing an inertial reference measurement system aboard ship from which to determine wave height.

The MarAd meeting scheduled to address this need has been postponed. As no immediate action that would involve NASA assistance seems likely, the Team has discontinued effort on this preliminary problem.

Boiler Water Measurement

Commercial ships monitor their boiler water chemistry twice daily for pH, alkalinity, conductivity, and chloride content. Inaccurate measurement can result in caustic embrittlement or scale depositions leading to tube overheating and burn-out. MarAd is sponsoring an effort to minimize human error, particularly with respect to reading interpertations, and to increase the number of components measured. The SRI Team furnished MarAd with information on the JSC water monitor system program, which uses commercially available sensors, systems packaged with automated readout, and standardization. MarAd is currently sponsoring a study with a boiler manufacturer to determine cost/need trade-offs. The SRI Team anticipated no further involvement with this preliminary problem until the current MarAd study is completed in mid-1977.

Measurement of Effective Atomization

Fuel consumption contibutes greatly to the operating expense of modern tankers. The effective atomization of a hot fuel stream must be measured to facilitate design of more efficient nozzles. Because standard photographic techniques are too expensive to be used within the combustion chamber, MarAd is seeking new techniques that will give this information. The SRI Team informed MarAd of relevant NASA expertise in laser Doppler and inline holographic techniques. Since MarAd is consulting directly with LeRC in determining availability of funds for studying effective atomization, no further Team action is anticipated.

Summary

From its first year of experience in interfacing with maritime and inland waterways agencies and associations, the SRI Team has concluded that it should curtail further active identification of appropriate problems and should respond only to those requests it receives for solutions that would have high potential impact. The Team has found that most of the problems being currently pursued by these agencies require near-term solutions. The time frames being considered generally preclude adaptation of technology designed initially for different purposes. Thus, although use has been and will continue to be made of NASA-developed technology to assist in solving the problems in waterways transportation, this area is not judged to be a potentially rewarding one for Team participation.

VI TRUCK-RELATED PROBLEMS

GENERAL

In October 1974, the SRI Team began studying problems of the trucking industry. The NASA TU Program was introduced during visits made to the American Trucking Association (ATA), representing the trucking companies, and to three organizations representing the truck manufacturers--the Heavy Duty Truck Manufacturers Association (HDTMA), and Truck Trailer Manufacturers Association (TTMA) and the Truck Body and Equipment Association (TBEA). The SRI Team also contacted numerous truck operators and manufacturers, particularly those associated with the HDTMA. As a result of these and subsequent meetings, the following list of preliminary problems was generated in early 1975:

- Particulate and other emissions
- Exterior and interior (cab) noise
- Electronic component reliability
- Fuel economy
- Aerodynamic drag and road spray reduction
- Component testing
- Propulsion systems
- On-board diagnostic equipment
- Nondestructive testing of bearings and structures
- Magnetic particle detection
- Improved insulation
- Corrosion protection for electrical connectors
- Nonfade paints
- Extended-temperature-range lubricants
- New metal alloys for new, hotter engines
- High strength-to-weight materials for structures for weight reduction
- Instrumentation for on-board test and evaluation
- Low-cost pressure transducer

- Hydraulic system contamination control
- Hydraulic seals for wide pressure range
- Strain gage instrumentation in truck environment
- Effects of impact loads on materials
- Railcar kingpin problem
- Bottom loading and vapor recovery operations; fail-safe valve technology for corrosive and/or hazardous materials
- Improved brake lining material
- Electrical connector standardization
- MVS-121 brake system, final stage manufacturer recertification tests
- Added axle performance tests
- Ride quality
- Fifth wheel lubrication material
- Worker-machine interface
- Load-sensitive suspensions

In 1976, the list of preliminary truck industry problems was revised by determining the status of the problems on the original list, which entailed examining recent technological advances from research programs relating to the problems. Work on some of the problems previously identified was discontinued because of the commercial availability of pertinent technology or evinced general lack of interest among manufacturers. Five preliminary problems from the 1975 list and four more recently identified problems were selected for technology searches on the basis of the potential impact of solutions to these problems and and the potential for identifying applicable NASA technology. These problems are described in Table VII.

Significant progress was made in the technology transfer process in 1975 and 1976 on three problems:

- Aerodynamic drag reduction

Table VII

REVISED LIST OF PRELIMINARY TRUCK PROBLEMS

Problem	Description
Exterior and Interior (Cab) Noise	EPA regulations will be in effect 1/1/78 (exterior noise level 83dba). Trucks now run at 83-86dBA. Future regulations will be implemented for lower noise levels. Majority of noise above 83dBA is produced by cooling system fan. Noise below 83dBA is produced by engine and other mechanical parts.
Propulsion Systems	Lower priority problem; however a highly efficient system would benefit industry. Considerable work is being carried out in this area.
Corrosion Protection for Electrical Connectors	Significant problem area. The entire electrical system on trucks appear to be a problem; entire system is exposed to environment.
High Strength-to-Weight Materials for Weight Reduction	Very cost oriented; could result in large savings to the industry.
Lubrication of Fifth Wheel	Present lubricant is quite messy and becomes contaminated with abrasive particles. Need for efficient, dry lubricant.
Improved Fan/Radiator	Important area requiring lightweight, more efficient systems.
Improved Adhesives and Techniques	Considerable technology available to this area, but any new applicable technologies might be useful to industry.
Harness and Use of Waste (Exhaust) Heat	New problem area with low priority at this time.
Recovery of Energy Dissipated During Vehicle Braking	New problem area with low priority at this time.

- On-board diagnostic systems
- Improved cooling systems and noise reduction

The progress made and current status of these problems are detailed in the following section.

Aerodynamic Drag Reduction

It has been estimated that 7% of the energy (including petroleum, coal, and natural gas) consumed in the United States is used to overcome the air resistance of road vehicles. A significant portion of this is unnecessarily burnt because of the lack of streamlining in the design of highway trucks. Although current truck designs do reflect consideration of air drag factors, they have also had to address the volumetric packing efficiency of a cubic shape.

In early 1974, NASA engineers at the Dryden Flight Research Center, Edwards Air Force Base, Edwards, California, conducted aerodynamic drag reduction tests on a box-shaped vehicle; results of these tests were detailed in "Drag Reductions Obtained by Modifying a Box-Shaped Vehicle" (NASA TM X-56027). Based on the results of this NASA-sponsored research, the DoT, through TSC, funded similar research at DFRC in a program to determine the amount of drag reduction obtained by the use of off-the-shelf commercial add-on devices for cab-over-engine highway trucks. The results were presented to an industry-wide seminar entitled "Reduction of the Aerodynamic Drag of Trucks", sponsored by DoT and the National Science Foundation and held at the California Institute of Technology. The report describing this work, "Aerodynamic Drag Reduction Tests on a Full-Scale Tractor-Trailer Combination with Several Add-on Devices" (NASA TM X-56028), was published in December 1974.

Results obtained showed that with only minimal modifications of truck design, and with the use of add-on wind deflectors, aerodynamic drag reductions of 24% could be achieved. Drag reductions of this magnitude resulted in fuel savings of approximately 40% at normal operating speeds.

NASA also found that a drag reduction as high as 60% could be achieved over a box-shaped vehicle by extreme aerodynamic redesign. This low drag truck configuration developed by FRC engineers, is illustrated in Figure 19.

Because of current space shuttle-related efforts no further work in this area is anticipated in the near future.

On-Board Diagnostic Systems*

To improve the safety, reliability, and operating economy of heavy-duty trucks, manufacturers are considering electronic system elements as additions or replacements for existing mechanical or fluidic elements, particularly sensors. Inexpensive, reliable transducers will be required as inputs for the types of systems mentioned. There are several potential advantages of electronic-based systems over present mechanical/electrical/fluidic systems. These are cost reduction, increased reliability, and lower maintenance effort using a single integrated control and diagnostic system as opposed to a collection of unrelated independent sensing, control and display devices.

In December 1974, the SRI Team uncovered a concept for a variable permeability torque transducer in a NASA Special Publication entitled "Measurement Technology" (NASA SP-5926 (03)); the transducer had the potential to become an inexpensive source of torque information and could also provide power information when electronically combined with a shaft RPM analog. If this instrument were to be further linked with fuel flow on air intake mass flow in some future on-board diagnostic and control system, direct engine efficiency readings could be obtained in "real time".

The device was actually built and tested, under contract to LeRC, but it was found to be rather sensitive to any lack of coaxial alignment between the sensing coil and the shaft. An improved version, based on eddy-current effects rather than on changes in permeability, has been designed and, if sufficient interest is evident, could easily be brought

* See Appendix B for problem statement.

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FIGURE 19 NASA LOW DRAG TRUCK CONFIGURATION to the testing stage.

The Team contacted instrument manufacturers, truck manufacturers associations, and the American Trucking Association (representing the operators) regarding the feasibility of using a power transducer in future on-board diagnostic systems, and received enthusiastic responses from each group. Three of the five companies contacted regarding possible development and manufacture of the concept decided not to pursue it, presumably because it would not complement existing product lines. Two instrument manufacturers are considering development as of this writing. Because this technology appears likely to result in a beneficial product, the SRI Team plans to contact other potential manufacturers in 1977.

Improved Cooling Systems* and Noise Reduction

Although conventional cooling systems are currently quite adequate for engine cooling, there is a need for quieter systems. New regulations for truck noise emittance, which will take effect in 1978, will necessitate reduction of exterior noise levels to below 83 dBA. The majority of truck noise above the 83 dBA level is produced by the cooling system fan. In attempts to reduce this noise, many manufacturers have increased radiator size to allow for slower fan speeds and have incorporated automatic fan shut-off switches that are engaged when engine/coolant temperatures are a low level. Even with these devices, cooling systems noise is still too high, and additional noise-reducing technology is needed.

A more compact or lighter weight cooling system is also desired, because efficient engine compartment space utilization will likely become more important in the next few years. Applicable noise reduction technology would be even more beneficial if it also resulted in decreased size and/or weight of the cooling system.

NASA heat pipe technology was investigated with help from Lewis Research Center and the NASA Technology Application Center at the University

* See Appendix B for Problem Statement

of New Mexico. Although the use of heat pipes would reduce engine weight and might result in minute fuel savings, heat pipes are not likely to produce more efficient engine cooling. In addition, their use would necessitate a change in engine design.

The use of woven metal filler technology, which NASA uses for heat dissipation in rocket nozzles, was also suggested by LeRC engineers. Woven metal fillers in a truck cooling system may, however, result in coolant contamination or restriction of coolant flow. These and other constraints are being addressed by LeRC in a technical feasibility study of the application of this technology to truck cooling systems. The study is expected to be complete in 1977.

The SRI Team will also continue to investigate NASA technology related to engine compartment redesign, sound deadening materials, exhaust muffler noise suppression systems, and auxiliary coolant systems.

VII ADDITIONAL TRANSPORTATION RELATED PROBLEM AREAS

- Recreational Vehicles
- Law Enforcement/Public Safety
- The Handicapped

In Fall 1975, the SRI Team introduced the NASA TU Program to the recreation vehicle industry. With the aid of the Recreation Vehicle Industry Association (RVIA), the following preliminary problem list was generated:

- Improved trailer wind stability
- Improved braking performance
- Low-cost, fire-resistant materials
- Fuel economy-weight savings
  -aerodynamics
- Low-cost, efficient waste disposal system
- Elimination of hydrogen off-gasing during battery charging
- Less dangerous energy source than LP gas
- Nonoxygen-consuming internal heaters
- Reduced infiltration of or detectors for CO into units
- Low-cost, nonvibration-loosening LP gas fittings
- Low-cost oxygen-sensing devices
- Gondola car monitoring instrumentation

Each of these problems was subsequently investigated relative to problem cause, potential impact of a solution, and the potential for marketing the applicable technology. In addition, NASA technology searches were initiated on most of the problems. As a result, most of the problems were eliminated, except for the needs for fire-resistant materials, ski-lift safety, and trailer stability. Section IV presents details on NASA fire-resistant material technology. Progress with the trailer stability problem is outlined below.

Trailer Stability*

Trailer sway is the cause of an increasing number of highways accidents. If a swaying trailer is not brought back to a stable position, it will zigzag behind the tow vehicle with greater intensity until the

* See Appendix B for Problem Statement

tow vehicle-trailer combination becomes uncontrollable. It is anticipated that the National Highway Traffic Safety Administration, will issue regulations aimed at correcting this problem. The recreation vehicle industry recognizes the need for improved vehicle dynamic design criteria to be implemented in the manufacture of trailers and has requested NASA assistance through the SRI Team.

The SRI Team recognized that the sophisticated techniques, facilities, and equipment used for characterization of the dynamics of complex space vehicle structures could be applied to a design criteria study for vehicle/trailer combinations. This NASA technology is currently being adapted to a railroad vehicle dynamics study that is part of the Track/Train Dynamics Program (see Section III) by Marshall Space Flight Center and their contractor, Martin Marietta Corporation.

The SRI Team familiarized MSFC and Martin Marietta with this problem. As a result, a technology utilization project was outlined to study the dynamics of trailer sway and to generate appropriate design criteria for safer tow vehicle/trailer combinations, including trailer hitches. The RVIA is currently evaluating the proposed project as well as funding possibilities. The SRI Team expects the project to begin in 1977.

<u>Ski Lift Safety</u>

Improved lift safety is a major concern throughout the skiing industry, particularly since the occurrance of two recent major accidents. On 26 March 1976, two gondola cars derailed at a large Colorado ski area, and fell over 100 feet, killing three and injuring nine others. A similar accident occurred on 10 March 1975 in Cavalese, Italy, resulting in 43 deaths.

The exact cause of these accidents is unknown; however, a better understanding of the dynamics of gondola lift systems, improved cable and car monitoring instrumentation, and improved cable life and performance are avenues being investigated by Vail Associates, Inc. SRI Team contact with Vail Associates in June 1976 revealed considerable interest in the potential application of NASA technology. Any application of space technology to serve Vail's problems would benefit the entire industry, since the remainder of the ski industry is certain to utilize the technology.

A problem statement on cable/car monitoring techniques or devices,* distributed to the NASA centers, resulted in a number of novel and economically sound suggestions. These included the use of sonic transducers, accelerometer switches, Ground Fault Interrupter devices, mercury switches, and light-emitting devices. In addition to a description of the devices, the suggestions included outlines of the overall instrument pacages needed and cost estimates for the equipment. As of this writing, Vail Associates is reviewing the suggestions for possible utilization.

Vail Associates also revealed additional technology needs for the ski industry:

- Improved lift-cable materials
- Improved cable design criteria
- General information on cable systems

These will be investigated further with Vail in late Spring 1977 following the current ski season.

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* See Appendix B for problem statement.

LAW ENFORCEMENT/PUBLIC SAFETY

In May 1976, a school bus accident on a Northern California highway resulted in the death of 28 students and injured 24 others. This provided the impetus for the SRI Team to investigate the possible use of NASA technology to prevent the occurrence of similar accidents. The SRI Team first contacted the California Highway Patrol because of its responsibility to inspect and regulate all buses used for student or farm labor transport. The Team also introduced the NASA TU Program to the Association of Police Planning and Research Organization (APPRO) and the U.S. Border Patrol. All three welcomed participation in the NASA TU Program. The CHP assigned one man to represent technology transfer activities and the APPRO established a Technology Transfer Committee.

The following list of preliminary problems was generated:

- Automatic in-motion weighing to develop a means of expediting the weighing of trucks at CHP scales. Weighing at speeds above 5 mph with computerized tabulation of axle and gross vehicle weight is desired.

- The relationship of human fatigue to hours of service or employment to evaluate the length of time drivers should be allowed to drive so as to ensure safe driving performance.

- Improved or new lightweight, low-cost materials that could be used to secure loads on trucks.

- Technology that could be utilized to provide vehicle stability rollover prevention for vehicles with a high center of gravity, such as tank trucks and mobile homes.

- A colorfast lens for blue lights that will eliminate the fading and discolorization experienced with current lighting materials.

- Improved lighting sources or lighting methods to increase visibility for driving in fog or other inclement weather driving conditions.

- Determination of human vision reflectability tolerance in regard to light sources reflecting from such items as mirrored windows and highly polished surfaces on tank vehicles.

- Airborne miniaturized medical equipment for monitoring and transmitting patient vital signs to the hospital while the patient's en route. To include temperature, pulse rate, respiration rate, and cardiac condition (EKG).

- Criteria to set an operating life span for helicopters and fixed-wing aircraft. Data should reflect point of diminished return, maintenance versus residual value, as well as fatigue factors for power plant and airframe.

- Solid-state miniaturized radio equipment for communications between aircraft and dispatch centers-ground units, aircraft and hospitals, and aircraft and control towers. System should include an extender system for use of aircrew when remote from aircraft.

- Protective coatings for helicopter main rotor and tail rotor blades to minimize the effects of atmospheric erosion.

- Equipment to enable a pilot or observer to see at night as well as in daylight without an artificial light source. The military has such systems now; however, a smaller, lighter, less expensive system would greatly benefit CHP operations.

- Police Vehicle location devices.

- Data compression technology to allow high speed transmission of reports from the patrol car to headquarters.

- Bomb detection devices or technology.

- Human detection devices for police use.

- Wall thickness and integrity NDE device to evaluate support tubing on aircraft after sandblasting during refurbishment.

One problem can be solved by commercially available NASA spinoff technology. Information on Telecare, the physicians' "Black Bag", and the TELECARE System was given to the CHP for use in its consideration of the airborne miniaturized medical equipment problem. Suggestions by ARC helicopter and wind tunnel engineers regarding use of tape on the tips of helicopter rotor blades to minimize atmospheric erosion were forwarded to the CHP to solve another problem. Because of existing technology and economic considerations, the SRI Team and the CHP decided to eliminate the problem of helicopter operating life span and solid-state miniaturized radio equipment from further consideration. In addition, during a technology search, NASA engineers informed the SRI Team of a commercially available NDE device applicable for the aircraft tubing NDE problem. The SRI Team provided the manufacturer's name to the U.S. Border Patrol so that they might utilize this new NASA technology, if desired.

Although the Law Enforcement/Public Safety area is the latest transportation related problem area to be investigated by the SRI Team, it has considerable potential for the application of NASA technology and technology transfer projects will begin in this area in 1977.

THE HANDICAPPED

The SRI Team has identified special needs to reduce the mobility limitations of the handicapped. To more effectively interface with the various government agencies concerned with the wide range of problems currently being addressed, the Team preferred to treat this as a separate category within its transportation responsibility. It is coordinating this new activity with the TU handicap effort in NASA HQ. At present, with the aid of California State agencies, Rehabilitation Engineering Centers, DHEW, DoT, and the VA, the Team is identifying mobility problems of the disabled.

VIII USER SERVICE

USER SERVICE

Although NASA technology will not solve all transportation industry problems, the user can often still be aided by the NASA technology utilization program and the SRI Team. By reviewing NASA literature concerning a particular problem, the user can frequently make progress toward the solution himself. In other cases, an SRI search will identify technology developed by another government agency or by a private sector company that the user can adapt for solution of his own problem. In either case, the SRI Team is able to serve the user by making him aware of recent technology.

The following is a summary of several preliminary problems for which specific NASA technology was not directly applicable but for which service could be provided to benefit the user.

Human Factors Engineering

The Massachusetts Bay Transportation Authority (MBTA) was interested in using more human factors engineering in their planning and design activities and therefore requested information on NASA's contribution to the field. The MBTA was supplied with a NASA data base computer search printout on the subject and subsequently a copy of NASA SP-5117, "Some NASA Contributions to Human Factors Engineering."

Training Methodologies

With the construction of new rapid transit systems in Washington, D.C., Atlanta, and Baltimore, and the planned construction in several other cities, there exists a need for improved universal training methods. A completely new staff with little or no previous experience must be trained to operate and maintain each new transit sytem.

The Transit Development Corporation initiated a study to determine the best technical training methods and teaching aids that can be adapted to its use and requested information on NASA's training program. A computer search of NASA's data base was initiated and evaluated by the SRI Team and the results were given to TDC for their use and possible subsequent implementation.

Rail Fastener

Fighton Company, a minority company, requested Lewis Research Center for NASA technology applicable to developing a new direct fixation rail fastener and the request was referred to the SRI Team. The SRI Team conducted two preliminary surveys--technology/market--and concluded that the two currently marketed direct fixation rail fasteners need no improvements and that applicable NASA technology is lacking.

Turbine Commuter Rail Cars

The Metropolitan Transportation Authority (MTA), New York City, in cooperation with UMTA, is evaluating several dual-power gas turbine/ electric commuter rail cars. The cars have two separate power plants so that they can operate on electrified as well as nonelectrified track, a combination that is common to some commuter railroad lines.

The MTA learned that NASA had done work on Brayton engines, and requested the SRI Team's help in locating the correct NASA center and the final report. The SRI Team referred the MTA to the LeRC Technology Utilization Office, from whom they obtained a copy of NASA SP-354, "DoT/NASA Comparative Assessment of Brayton Engines for Guideway Vehicles and Buses."

The MTA subsequently reported that the LeRC report was useful in their evaluation.

Telemetry and Instrumentation

The Southern Pacific Transportation Company (SP) is interested in applying NASA technology (including instrumentation and sensors) to onboard train monitoring both for research and normal operation.

A meeting arranged by the SRI Team brought Ames Research Center scientists together with the Southern-Pacific Railroad Engineering and Research Department to discuss several potential transfers. These included optical couplers for strain gage measurement telemetry, infrared TV with ARC video band suppression technique applied and microwave transmission for outside yard train surveillance, and microprocessor chips for mechanical diagnostics.

In addition, the SRI Team gave the SP a copy of "Telecommunications Systems Design Techniques Handbook" (NASA TM 33-571). The SP may utilize some of these concepts in future research projects.

Rail and Wheel Profilometer

The Association of American Railroads requested SRI Team/NASA assistance in locating a profilometer for nondestructive profiling of the cross section of rail heads and wheel rims. A NASA data base search aided identification of applicable profilometer work at Ames Research Center, Johnson Space Center, and Marshall Space Flight Center. Particularly applicable is Tech Brief 71-10534, "Multifrequency Laser Beams for Holographic Contouring." Details on this technique as well as several others (i.e., moire gauging, holographic interferometry, and close-range photogrammetry) suggested by experts were assembled, evaluated, and given to the AAR. Although the AAR has not yet implemented any of these techniques, the technology survey was beneficial to the AAR's efforts.

Materials and Structures Technology

The Association of American Railroads is becoming increasingly interested in preventing the failure of steel components (e.g., rails, wheels, bolsters) used in the railroad system so as to prevent accidents and reduce maintenance. To achieve this objective, the AAR Metallurgy Group is studying the characteristics of the steel currently used and is interested in the potential application of diagnostic techniques.

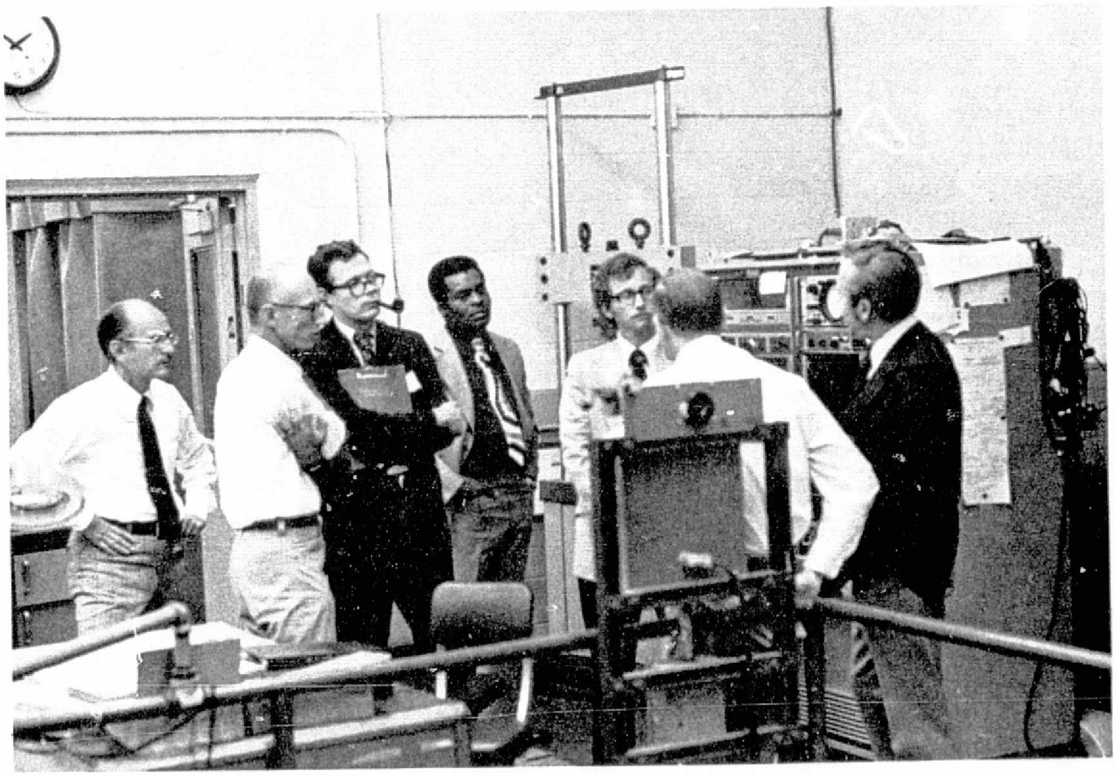
The SRI Team was aware that the Materials and Structures Division of Lewis Research Center (LeRC) is conducting extensive work with aerospace materials and practical, efficient ways to use them in aircraft and space vehicles. Groups within the division are working with alloys and composite materials and structures, and are studying surface protection, materials applications, fatigue, and fracture. When the SRI Team suggested that some of the techniques developed and used at LeRC might be applicable to the AAR effort, the AAR Metallurgy Group requested a meeting with LeRC scientists to identify potentially transferrable technology. The SRI Team arranged for the AAR Metallurgy Group to meet with scientists and engineers at LeRC on 21 July 1976. The AAR was interested specifically in LeRC technology concerning induced fracture and crack propagation, test design and procedures, nondestructive evaluation for testing and diagnostics of microcracks and subsurface cracks, and laboratory equipment and test fixtures. Discussions with LeRC scientists with expertise in these areas and a tour of the laboratory led to the identification of appropriate LeRC technology potential applicable to the AAR's programs. Discussions continued during the tour as shown in Figure 20. The possible application of composite materials in the railroad industry also was discussed.

The AAR engineers were given LeRC reports providing greater detail on the subjects of interest, and they are reviewing these reports to determine technology applicable to their needs.

Highway Noise

The Washington State Department of Highways sought SRI Team assis-

(a) INFORMATION EXCHANGE



(b) LABORATORY TOUR

SA-3670-54

FIGURE 20 PARTICIPANTS IN AAR AND NASA-LEWIS MATERIALS AND STRUCTURES TECHNOLOGY MEETING tance to understand noise propagation before attempting to solve a highway noise problem. The Team provided several NASA documents on noise attenuation, such as "Ordered Structures and Jet Noise," NASA CR-134733.

IX SRI TEAM PUBLIC AWARENESS ACTIVITIES

PRESENTATIONS

Several times during April 1975, the SRI Team provided visibility for the NASA TU program. The Team arranged for a TU presentation to be made to the membership at the annual meeting of the Heavy Duty Truck Manufacturers Association. Mr. Jeffrey Hamilton of NASA HQ addressed the group on NASA's TU program, after which a film depicting the full-scale truck wind-drag tests being done at FRC was shown. The NASA presentation was part of a program that included addresses by the Secretary of Transportation and by the Assistant Secretary of Commerce for International Trade.

Presentations describing the NASA TU program were also made to the Transportation Systems Division of General Motors Corporation and the Transportation Systems Operation of the Ford Motor Company. Mr. Clark Henderson, SRI Senior Staff Scientist, participated in these discussions. Interest at Ford was strong and specific topics will be pursued with them.

In August 1975, Team member Andrew Loomis gave a presentation describing "The NASA Technology Utilization Program," to the Recreation Vehicle Industry Association at their annual meeting. The presentation covered the history of NASA's TU effort, the SRI TAT methodology, and how the TU program might benefit the recreation vehicle industry.

In May 1976, Team Leader Tom Anyos participated in a Clemson University conference entitled "Technology Exchange Between the Textile Industry and Government." At this conference he presented an outline of team operations and encouraged the representatives of the textile industry in attendance to take advantage of the resources offered by the Technology Utilization program.

PUBLICATIONS

Several publications have resulted from the technology transfer efforts of the SRI Team. Some of these were generated by SRI Team members and others were published by organizations interested in the applications of NASA technology, such as the Transit Development Corporation and the Heavy Duty Truck Manufacturers Association.

In October 1974, Team member James Wilhelm presented a paper in the Design Technology Transfer portion of the Design Engineering Technical Conference of the ASME held in New York City. Copies of the paper were also disseminated to conference attendees. An abstract of the paper is given in Exhibit 1.*

Later in 1974, the benefits of participation in the Technology Utilization effort were explained to the nation's trucking industry in an article that appeared in Transport Topics, the national newspaper of the motor freight carriers. This article is given in Exhibit 2.

The SRI newsletter (28 February 1975), published biweekly and distributed to 3,000 readers throughout the world, contained an article on the Team's newest area of assistance, the trucking industry. The article is reproduced in Exhibit 3.

An effective liaison has been established between the SRI Team and the Transit Development Corporation (TDC), a nonprofit scientific and educational organization whose purpose is to pursue and foster research and development projects relative to urban mass transit systems and to make its findings available to the public, governmental bodies, and the transit industry. Evidence of this liaison with both NASA and SRI was given in TDC's recently completed report, "Safety Priorities in Rail

* Exhibits are given at the end of this section.

Rapid Transit," prepared for the Urban Mass Transportation Administration. The report contained the acknowledgement shown in Exhibit 4. Two other excerpts from the report are also of interest and are given in Exhibits 5 and 6.

NASA and the SRI Team also received visibility through the publication of a special urban mass transit issue of Technology Applications Notes, which is presented in Appendix C. This issue was seen by a large segment of the transit industry at the American Public Transit Association's Rapid Transit Conference held in Washington, D.C. Copies of notes were also mailed to the SRI Team's users in the transit industry.

In October 1975, the SRI Team arranged for key representatives of the trucking industry to visit the Marshall Space Flight Center, to learn of NASA's capabilities and expertise in those areas of interest to the industry. The meeting and its results were outlined in an HDTMA bulletin, which is reproduced in Exhibit 7.

Exhibit 1

TECHNIQUES OF TECHNOLOGY TRANSFER: THE NEED FOR PRIVATE SECTOR INVOLVEMENT

by
James P. Wilhelm
Tom Anyos

NASA Technology Applications Team
Stanford Research Institute

Abstract

The National Aeronautics and Space Administration has for some time actively pursued the transfer of aerospace technology to public areas of concern. One aspect of this effort matches problems in the public sector with solutions in the aerospace knowledge bank. To expedite this matching process, the NASA has established technology applications teams at several interdisciplinary research institutes.

One such team has been funded at Stanford Research Institute. This team has been in operation for almost five years. Coupled with its technology transfer mission has been the assignment to develop a greater understanding of the technology transfer process and to expedite the transfer operation to the greatest extent possible.

In the course of the team's activities, the need for private sector interest and involvement was clearly demonstrated. It soon became clear that almost irregardless of the technological impact a new technology might offer, without private sector interest or involvement, it will rarely reach the marketplace. The experience of the SRI team in dealing with this sector has taught it how to generate interest and enthusiasm for the utilization of newly developed technologies.

Exhibit 2

TRANSPORT TOPICS
DEC 16 1974
WEEKLY - 25,000

HDTMA Invites Views on Use Of Space Skills in Trucking

The Heavy Duty Truck Manufacturers Assn. is soliciting comments from throughout the industry on the possible application of space technology to truck manufacture and operations.

HDTMA is working with the Stanford Research Institute on the search. The research unit, under a contract with the National Aeronautics and Space Administration, is studying ways to make NASA's vast store of technology available to private industry.

The space agency has a series of "applications technology teams" to apply to earthbound problems the skills and equipment used in spaceflight. The teams are charged with seeking out problems of special concern and arranging for adaptive engineering to convert technological solutions into viable products.

One of the teams is the SRI unit, which is studying the truck industry. The team expects, said an SRI spokesman, "to uncover a wealth of space-age technology applicable to heavy-duty trucks."

"The time is ripe for exploring all technology that may help manufacturers meet the present and upcoming" federal requirements, the HDTMA said. It plans to meet next year with the SRI group to identify the major problems and discuss what available technologies can best be applied.

The first step, however, will be for HDTMA to obtain the background information the participants will need for the initial meeting.

The association is inviting views on such matters as improved fuel economy, lowering wind resistance, fleet-testing of brake systems, noise reduction, on-board diagnostic equipment, corrosion protection and non-fading paints, and high strength-to-weight materials.

The joint effort, said F. Murray Callahan, general counsel of HDTMA, could "result in new major technical breakthroughs that might not have occurred for a generation to come."

The HDTMA's address is Suite 1300, 1700 K St., N.W., Washington, D.C. 20006.

Exhibit 3

SRI team solving truck problems, use space science

"The wheels that make the world go round" is one of the slogans in the trucking industry.

Helping to keep those trucking wheels moving is SRI's Technology Application Team, headed by Tom Anyos.

The National Aeronautics and Space Administration (NASA) has contracted SRI to actively apply the technology developed during America's space race to transportation problems in the public and private sector.

Ken Hirschberg, a research engineer in SRI's team, has been meeting with major national trucking associations to determine whether trucking problems might be improved with existing space technology.

Hirschberg says a solution to many of their problems will result in safer, more ecological and less expensive trucking.

Skyrocketing fuel costs, for example, is a major concern among both truck manufacturers and trucking firms. Engine improvements, re-adapted from NASA's work, would result in more efficient use of engines.

NASA technology, Hirschberg points out, may also be helpful for helping the trucking industry meet the growing number of requirements and restrictions being legislated by federal and state governments.

Weight regulations of trucks was one example cited by Hirschberg. "If we could build a lighter truck structure with space materials, truckers could carry more goods, thus saving energy and money."

Federal health and safety regulations now impose a limit on the level of noise emitted from the engine. "Perhaps we could build a quieter engine and insulate the cab."

Other concerns facing truckers are improved braking systems, truck installed diagnostic equipment to sense and record mechanical failure, and devices to reduce wind drag for better fuel economy.

After the SRI team and the truckers have established what the most pressing problems are, the team will begin matching the problems up with NASA know how.

Who would have ever dreamed that space capsule science would end up resting in a truck stop? □

Exhibit 4

ACKNOWLEDGEMENT FROM
SAFETY PRIORITIES IN RAIL RAPID TRANSIT*

"Numerous individuals and organizations have contributed valuable information and services necessary for the completion of this task. Particular thanks are expressed to the uncompensated members of the Safety Advisory Board; to the Rail Transit Executives who made the project possible by generously donating the services of the Board members to industry manufacturers and suppliers, and to:

Mr. E. Boyle - UMTA - DoT
Mr. I. Litant - TSC - DoT
Mr. R. Pawlak - TSC - Dot
Dr. S. Riccitiello - NASA
Mr. R. Miner - NASA
Mr. J. Wilhelm - Stanford Research Institute
Mr. D. Gross - National Bureau of Standards
Dr. D. Raskin - Metropolitan Transportation Authority, NY
Mr. E. Schafran - Port Authority of New York and New Jersey

The TDC report will be of great interest to the transit industry and to government because it describes the results of TDC's task of developing and designing a plan reflecting the safety priorities and requirements of the rail transit operating properties."

* Final Report, March 1975, United States Department of Transportation-Urban Mass Transportation Administration.

Exhibit 5

"TDC and the Board interfaced with government agencies, such as NASA, from the early stages of the project, and permitted TDC to draw upon their technological resources and thus assure effective and economical development of hazard solutions. When problem areas received adequate identification, suppliers of equipment and services were requested to furnish technical proposals and informal cost information based upon Advisory Board recommendations. This interface activity is best illustrated by the effective liaison, which will be further discussed in Section 4, that was established between TDC and Stanford Research Institute, the NASA Contractor for technology transfer in the area of mass transit."

Exhibit 6

Cable Protection

"Coincident with the transit vehicle materials problem was a concern with other materials in the transit environment. Recorded incidents in recent years (TDC Monograph Series 500 - "Smokeless Cable") have emphasized the need for cabling that will be slow burning, smokeless, and non-toxic for use in the subway environment.

The Board was aware that a smokeless cable research program had been developed by TDC, utilizing extensive background work done by the New York City Transit Authority. Of equal importance to the development of smokeless cable was the protection of existing cables in the subway confined area environment. Any solution to this problem would have to assure that the electrical and mechanical properties are not diminished for service life and efficient operation of the cable. TDC discussed with Stanford Research Institute, Menlo Park, California the possible application of NASA-developed technology in the field of intumescents for cable protection. Preliminary findings indicated that intumescing materials currently available from the space program are heavy toxic gas producers when exposed to flame.

Discussions with NASA/Ames Research Laboratory, Moffett Field, California, indicates that they will be conducting toxicity tests of intumescing-type materials, which could be used for the protection of existing cable installations. If the toxic qualities of the materials are deemed low enough, possible systems for their use in cable protection could be developed. In any event, the candidate solutions for cable protection must be analyzed to assure that they do not ultimately introduce a hazard greater than the benefit yielded."

Exhibit 7

BULLETIN

No. 10
October 8, 1975

From HDTMA

HDTMA, NASA, SRI MEET ON TRUCK INDUSTRY FUTURE

On September 30, 1975, the Marshal Space Flight Center, Huntsville, Alabama, hosted a day-long meeting between NASA officials, HDTMA, SRI and representatives of a number of the major manufacturers and component producers of our industry. Among those present were representatives of Dana, Eaton, General Motors, Mack, Martin Marietta, PACCAR and Rockwell International. This first joint session between NASA and the industry is the result of over a year's work and represents the cooperative efforts of NASA, Stanford Research Institute and this Association. F. Murray Callahan, Vice President and General Counsel, coordinated the project for HDTMA. NASA has been tasked with the responsibility of transferring its skills and technology to the private industrial sector and its enthusiasm for the project was well demonstrated at Huntsville. Those attending were greeted and conducted throughout the day by Mr. Aubrey Smith, the Director of Technology Utilization in Huntsville.

After an interesting discussion of the functions and capabilities of the Marshal Center, they were briefed on a NASA-industry cooperative program through which the railroads of the United States are cooperatively working with NASA in solving some of the problems in track/train dynamics. NASA has received a government grant to study the influence of railroad car dynamics on derailment. The visitors were briefed on the progress of this study to date and the likely approaches to solve this long-standing problem. NASA also described its project for measurement of highway road bed characteristics and profiles.

Another very educational presentation was made concerning the possible use of computers in design and manufacture for the truck transportation industry. There was a discussion of NASTRAN (NASA Structural Analysis), a computer system for structural analysis which is now widely used by NASA, other government agencies and industry. It first became available to the public in late 1970. NASTRAN's variety of analytical capabilities have been widely used in many fields and disciplines, from stress analysis of the heart to helicopter transmission vibration/noise reduction.

Following lunch, through which the business discussion continued, the group visited several of the Marshal Center's laboratories including those involved in materials development and advanced lubricants. There was great interest in both areas particularly the non-metallic materials, polymers, composites, etc. The many qualities of these very strong and very lightweight materials were effectively discussed by our NASA briefers. The engineers were also impressed by the phenomenal properties of many new lubricants being developed by NASA and their possible application in the automotive field. This first meeting did not afford time enough to visit the many other laboratories at the Marshal Space Center but served to impress one and all of the magnitude of the abilities and skills possessed by just one NASA center.

The last formal session of the day was an exchange of views between industry representatives and NASA officials on a wide range of problems facing the truck industry. Stanford Research had identified a list of over 40 problems from fuel efficiency to noise reduction to drag and spray reduction. It was apparent that the utilization of this technology, both on shelf and that to be developed by cooperative effort, will require many additional meetings and the establishment of priorities.

In the latter regard, it is evident that the priority list must be drawn up with a view to what is being mandated by the government. We know that uppermost in the industry's concern is the proposed EPA standard for noise levels in a heavy duty vehicle. Of interest here is the NASTRAN model for the Boeing helicopter that has been developed and applied to reduction of transmission vibration noise at its source. "The objective of this work is to generate analytical tools that will provide the capability to perform trade studies during the design stage of a program. This capability will yield optimized drive train components that are dynamically quiet with inherently longer life with reduced vibration and attendant noise levels." If such techniques and technology can be applied to a helicopter, they can certainly find application in heavy duty trucks.

It is now anticipated that a second NASA-industry meeting will be held soon with the likelihood that noise reduction will be a key element of the discussions. Langley, Virginia, and Cleveland, Ohio, were mentioned as possible sites for the next meeting. It was apparent that the initial session exceeded the expectations of both industry and government. With such a good beginning, HDTMA looks forward to continuing our productive partnership with NASA and SRI.

****

At the time that we went to press, HDTMA staff members were preparing to cover the DOT Joint Task Force hearing on Long-range Commercial Vehicle Goals Compatible with Environmental, Safety and Economic Objectives and to meet with ATA officials regarding the Heavy Duty Truck Emissions Amendment adopted by the Health Subcommittee of the House Interstate and Foreign Commerce Committee. Our next bulletin will apprise you of developments on these two subjects and the Ways and Means Committee action on Foreign Source Income.

****

We wish to thank the members of the Association for sending in their logos which have made an attractive addition to our offices in Washington. If your company hasn't found time to comply with our request, we would appreciate receiving your corporate symbol in the near future. Thank you for your cooperation.

X REFERENCES

1. "Evaluation of Coatings on Coastal Steel Bridges," Research Report No. M & R645135, Division of Highways, State of California, January 1969.

2. W. J. Paton, "Performance Characteristics of Zinc-Rich Coatings Applied to Carbon Steel," NASA Technical Note TN D-7336, Kennedy Space Center, July 1973.

3. R. R. Ramsey, "Zinc Coatings in the Florida Experience," National Zinc-Rich Coatings Conference, Chicago, December 1974.

4. D. S. Wilson and J. L. Frarey, "Investigations of a Bearing Fault Detector for Railroad Bearings," Shaker Research Corporation, Ballston Lake, N.Y., 1976.

5. W. N. Clotfelter and E. R. Risch, "Ultrasonic Measurements of Stress in Metroliner Wheels," Marshall Space Flight Center, Huntsville, Alabama, 1975.

6. J. D. Ingham et al., "Fire and Smoke Retardant Materials for Mass Transit Vehicles," Report Ref. 784-20401-9-3460, Jet Propulsion Laboratory, Pasadena, California, 1976.

APPENDIX A

USER AGENCIES BENEFITTING FROM SRI TEAM ACTIVITIES

HIGHWAY INDUSTRY USERS OF NASA TECHNOLOGY

American Public Works Administration

Baltimore Public Works Department

California Department of Transportation

California Innovations Group

Delaware Department of Transportation

Federal Electric Corporation

Federal Highway Administration

Florida Department of Transportation

Golden Gate Bridge, Highway and
Transportation District

Idaho Transportation

Iowa Department of Transportation

Maine Department of Transportation

Maryland Department of Transportation

National Highway Traffic Safety Administration

New York Department of Transportation

North Carolina Department of Transportation

Office of Minority Business Enterprises

Ohio Department of Highway Safety

Oregon State Highway Division

Pacific Gas and Electric Company

Pennsylvania Department of Transportation

Philadelphia Mayor's Science Advisory Council

Santa Clara County, California

Santa Clara Valley Water District

Texas State Department of Highways and Public Transportation

University of Washington

Vermont Highway Department

Washington State Highway Commission

RAILROAD INDUSTRY USERS OF NASA TECHNOLOGY

Abex Corporation

Association of American Railroads

Burlington Northern

Chessie System

Chicago and Northwestern Transportation Company

Chicago, Rock Island, and Pacific Railroad Company

Chicago, Milwaukee, St. Paul, and Pacific Railroad Company

Consolidated Rail Corporation (ConRail)

Federal Railroad Administration

General Electric Company

Illinois Central Gulf Railroad Company

Missouri Pacific Railroad Company

Railway Progress Institute

Southern Pacific Transportation Company

Southern Railway Company

The Atchison, Topeka & Santa Fe Railway Company

The Western Pacific Railroad Company

Transportation Systems Center

Union Pacific Railroad

RAPID TRANSIT INDUSTRY USERS OF NASA TECHNOLOGY

American Public Transit Association

Bay Area Rapid Transit District

Boeing Vertol Company

Chicago Transit Authority

General Motors Transportation Systems Division

Mass Transit Administration, State of Maryland

Massachusetts Bay Transportation Authority

Metropolitan Atlanta Rapid Transit Authority

Metropolitan Dade County Office of Transportation Coordination Administration

New York City Transit Authority

Port Authority Transit Corporation

Regional Transit Authority, Cleveland

Southeastern Pennsylvania Transportation Authority

State of Florida Department of Transportation

The Garrett Corporation

Transportation Systems Center

Urban Mass Transportation Administration

Washington Metropolitan Area Transit Authority

TRUCKING INDUSTRY USERS OF NASA TECHNOLOGY

Heavy Duty Truck Manufacturers Association (HDTMA), Washington, D.C.

Truck Trailer Manufacturers Association (TTMA), Washington, D.C.

Truck Body and Equipment Association (TBEA), Washington, D.C.

American Trucking Associations (ATA), Washington, D.C.

General Motors Truck and Coach Division, Pontiac, MI

Dana Corporation, Toledo, OH

General Motors Transportation Systems, Warren, MI

Consolidated Freightways, Menlo Park, CA

Crane Carrier Company, Tulsa, OK

Freightliner Corporation, Portland, OR

International Harvester Corporation, Chicago, IL

Kenworth Truck Company, Seattle, WA

Autotronic Controls Corporation, El Paso, TX

Hamilton Standard Company, Windsor Locks, CT

Mack Trucks, Allentown, PA

Paccar, Inc., Renton, WA

Parker-Hannifin Corporation, Cleveland, OH

Peterbuilt Trucks, Newark, CA

Transportation Systems Center, Cambridge, MA

TRW, Redondo Beach, CA

TRW-ROSS Gear Division, Lafayette, IN

RECREATION VEHICLE INDUSTRY USERS

OF NASA TECHNOLOGY

Airstream, Inc.

Recreation Vehicle Industry Association

Vail Associates, Inc.

LAW ENFORCEMENT TRANSPORTATION USERS OF NASA TECHNOLOGY

Association of Police Planning and Research Officers

Atherton Police Department, CA

California Highway Patrol

Colma Police Department. CA

Fresno Police Department, CA

Modesto Regional Criminal Justice Training Center, CA

Sacramento Sheriff's Department, CA

San Joaquin County Sheriff's Department, CA

San Mateo Police Department, CA

Santa Cruz Police Department, CA

Tracy Police Department, CA

U.S. Border Patrol

WATERWAYS USERS OF NASA TECHNOLOGY

Bertram Yacht

Chris Craft Corporation

Maritime Administration, U.S. Department of Commerce

Naval Sea Systems Command, U.S. Navy

United States Coast Guard

APPENDIX B

PROBLEM STATEMENTS

PROBLEM STATEMENT

FIRE RESISTANT PANEL

A problem in Transportation undertaken by the Technology Applications Team at Stanford Research Institute sponsored by NASA's Technology Utilization Office

September 1974

What Is Needed

Fire resistant, non-metallic materials for use in interior wall and ceiling panels on rail rapid transit cars.

Background

The Urban Mass Transportation Administration has let a contract for the construction of two Advance Concept Train (ACT) rail rapid transit demonstration cars. The objectives of the program are to advance the state-of-the-art of rail rapid transit car design and construction by applying the benefits of advanced technology. For improved safety, fire resistant interior materials are required. Specifically, there is a need for fire, graffiti, and vandal resistant non-metallic materials for interior wall and ceiling liners. Currently used molded melamine, polyester fiberglass and acrylic fiberglass panels do not satisfy the specified fire resistance requirements.

Constraints and Specifications

Using ASTM Test Method E-162, the flame spread index, I_s, of the material must be less than 25. With regard to smoke evolution, the specific optical density, D_s, must be less than 200 after a 10 minute test. The material also must not exceed values stipulated in the Boston Fire Code and DOT, Federal Highway Administration Standard No. 302 "Flammability of Vehicle Interior Materials." The material should not be affected by industrial compounds used for cleaning purposes and it should have an abrasive resistant surface capable of withstanding the effects of vandalism. Resistance to graffiti marking is also desirable. A 20 year life is expected and a production volume price of $1-2 per square foot is desirable.

The following physical properties are also suggested:

Property	Test Value	Test Method
Tensile	10.0×10^3 p.s.i. average-minimum	ASTM D-638 D-651
Moisture Absorption	.5% maximum	ASTM D-570
Izod Impact Resistance	15.1 lbs./inch average-minimum	ASTM D-256
Barcol Hardness	50 average minimum	

For further information, contact:

James P. Wilhelm, Technology Applications, SRI, Menlo Park, California 94025. Telephone (415) 326-6200, extension 3520.

This Problem Statement calls to your attention significant technological needs in an important area of concern in the public sector. We hope to bring to bear on this problem the information and expertise that resides in NASA. If you feel you can contribute, please relate your ideas to the Technology Utilization Officer at your installation, or to the team representative named in the statement.

PROBLEM STATEMENT

FIRE RESISTANT MATERIALS

A problem in Transportation undertaken by the Technology Applications Team at Stanford Research Institute sponsored by NASA's Technology Utilization Office

November 1974

What Is Needed

Fire resistant, non-metallic materials for use in the interior of rail rapid transit cars for thermal and acoustic insulation, wall and ceiling panels, floor covering and carpeting, seat cushions, and seat covers.

Background

Lives have been lost, and extensive property damage has occured in subway fires in the past. For passenger safety in case of fire in a rapid transit car, especially in the confines of a tunnel, more fire resistant, low smoke, and low toxic gas-producing construction materials are needed. Improved materials are needed for thermal and acoustic insulation, wall and ceiling panels, floor covering and carpeting, seat cushions, and seat covers. In addition to fire resistance the exposed materials must be washable using commercial cleaning agents. Graffiti and vandal resistance are also desirable but not required properties.

Materials currently used and their fire resistance characteristics are listed on the attachment. As the materials specified by different transit authorities vary, the list includes three different car types (distinguished as A, B, and C).

Constraints and Specifications

All combustible materials with the exception of seat cover fabric shall be required to pass or equal to ASTM Specification E-162 (latest revision), Radiant Panel Test with a flame propagation index (I_s) not exceeding 25, with the additional provision that flaming of any drippings shall not be allowed. Furthermore, foam samples must be supported by wire screening to prevent them from falling from the sample holder during the test.

The seat cover fabric must self-extinguish when tested vertically in accordance with FAA Regulation 25.853, Appendix F (b), with the following changes: the average burn length may not exceed 6 inches, and the average flame time after removal of the flame source may not exceed 5 seconds. Flaming of any drippings shall not be allowed. Furthermore, the samples of material shall, after 15 minutes immersion in water and thorough drying, still conform to this test.

The combustible materials must be tested for smoke emission in accordance with the National Bureau of Standards Technical Note 708, "Interlaboratory Evaluation of Smoke Density Chamber," December 1971, Appendix II, "Test Method for Measuring the Smoke Generation Characteristics of Solid Material," dated September 1971. The specific optical density, D_S, determined in accordance with the test may not exceed 100 within 90 seconds after the start of the test, and may not exceed 200 within 4 minutes after start of the test. The only material excepted is neoprene foam cushioning. (Department of Transportation Guidelines for Flammability and Smoke Emission Specifications - TSC-74-LFS-2).

<u>Further Questions Should Be Directed To:</u>

James P. Wilhelm, SRI Technology Applications Team, 333 Ravenswood Ave. Menlo Park, California 94025. Telephone: (415) 326-6200, extension 3520.

This Problem Statement calls to your attention significant technological needs in an important area of concern in the public sector. We hope to bring to bear on this problem the information and expertise that resides in NASA. If you feel you can contribute, please relate your ideas to the Technology Utilization Officer at your installation, or to the team representative named in the statement.

CURRENTLY USED MATERIALS (BY PART) AND FIRE RESISTANT CHARACTERISTIC

PART/MATERIAL	FIRE-RESISTANT CHARACTERISTIC
Thermal and acoustic insulation	
A. walls - fiberglass	
walls - closed cell neoprene foam	meets NFPA standards
roof, floor - urethane foam	meets NFPA standards
between roof and side - closed-cell flexible polyurethane foam	burn rate $\cong$ 1.5 in./min. in horizontal bar test
B. fiberglass	permanently fire resistant
C. fiberglass (Gustin Bacon, type #75 Ultralite	flame spread index $I_s < 50$ (ASTM E-162)
Wall and ceiling panels	
A. polyester reinforced fiberglass	
B. melamine (Textolite TX 4300)	
melamine (Consoweld Dusky Walnut VT-W-48)	
window masks - fiberglass	permanently fire resistant
C. fiberglass	
melamine	
Floor covering	
A. heavy weight wool velvet weave with level loop pile	flame spread class 75 (ASTM E-84)
lead impregnated vinyl and polyurethane foam carpet pad	
B. RCA Rubber Co. Transit Flor (vinyl asbestos)	
C. wool carpet	flame spread < 75 (ASTM E84-61)
polyester back	
Seat cushion	
A. resilient molded foam	
B. neoprene foam padding	flame spread 25 or less (ASTM E166-67)
C. resilient foam of latex urethane (SPI Type II base)	exceeds values stipulated by Boston Fire Code and DOT FHWA Standard #302
Seat covers	
A. vinyl and fabric	meets NFPA standards
B. vinyl coated knit nylon (Uniroyal Naugahyde Decor Polymeric Vinyl, Supreme Grade DC-16)	meets Federal Specification CCC-A-680, latest issue, Treatment A-1

Seat covers (continued)

C. plastic coated fabric and woven upholstery fabric	exceeds value of Boston Fire Code and DOT FHWA Standard #302

Seat frame

B. fiberglass (glass reinforced polyester)

Weathering strips and door seals

A. elastomeric material

Door guide

A. polyvinyl chloride

Hand grip

A. polyvinyl chloride

Side windows

A. laminated safety glass

B. laminated safety glass

C. laminated safety glass

PROBLEM STATEMENT

SYSTEMS ASSURANCE

A problem in Transportation undertaken by the Technology Applications Team at Stanford Research Institute sponsored by NASA's Technology Utilization Office

November 1974

What Is Needed

Systems engineering technology and management methodologies to be applied for improved and integrated quality assurance, reliability analysis, maintainability, availability, and safety of urban rail rapid transit systems.

Background

With the growing need for urban public transportation, significant construction and expansion of rail rapid transit systems in the United States is planned. The increased use of automation in train control is likely to be implemented with these systems. Automatic train control (ATC) includes automatic train protection (performs train and track surveillance, train separation and interlocking, and overspeed protection), train operation (performs on-board velocity regulation, stopping, door operation, and starting), train supervision (performs centralized train scheduling and operational implementation, yard train control, ATC system maintenance management, and overall system maintenance management), and communication systems (performs data and voice communications to unify and support all other elements of ATC).

The advantages of automatic train operation include increased safety, reduced operating costs, increased passenger comfort, increased system train capacity, reduced service disruptions, and improved train maintenance coordination. However, the increased complexity of the automation can lead to more frequent failures, more maintenance, and less system availability. To overcome these problems, quality assurance, reliability, maintainability, availability, and safety must each be designed and integrated into the overall system. This approach would be initiated during the early planning stages of a new transit system.

IMPROVED UNDERSTANDING OF TRUCK DYNAMICS AND RIDE QUALITY

T-35
May 1975

KEY WORDS

Math modeling, Simulation, Engineering Mechanics, Stress analysis, Instrumentation, Ride quality, Driver effects, Road testing, Roadbed compliance.

APPLICATIONS

Optimal truck chassis and suspension design; improved ride quality, handling and increased safety.

BACKGROUND

In order to design trucks with improved dynamic characteristics, it will be necessary to fully characterize the dynamics and interactions of the tractor, trailer(s) and roadway. This characterization should produce a math model that includes all the important elements contributing to truck dynamics (e.g. roadway, loading, braking, acceleration, coupling, suspension, wind drag, tires, steering, chassis stiffness, and so on). There are legal in addition to mechanical considerations that must be taken into account when evaluating possible truck improvements. Many physical dimensions of the system are regulated by law, i.e. the gross weight, the length, width, height, weight distribution on axles, etc. It may not, for example, be possible or desirable to locate an axle at the center of percussion on a trailer, so the resulting dynamic forces will have to be accommodated by other means. Flexure of a trailer chassis sometimes results in fore and aft pitching of the cab. A lack of isolation between the driver and certain frequency components present in the motion of the truck sometimes causes undesirable physiological effects. Changes in loading of the truck may not be compensated by the suspension. It is not uncommon to see the wheels of some unloaded trucks bouncing clear of the roadway at highway speeds.

There is great interest among truck operators and manufacturers in truck dynamics. A fuller understanding of the subject in the form of an easily usable math model would be a significant contribution to the trucking industry. The effort to develop a truck dynamic model will probably parallel the present work being done by DoT/NASA on track-train dynamics.

Ideas or questions on this subject may be addressed to the NASA Technology Applications Team, Stanford Research Institute, 333 Ravenswood Ave., Menlo Park, CA. 94025; Attention: Mr. Kenneth Hirschberg or to the Technology Utilization Officer at your installation.

NASA Technology Utilization Opportunity

National Aeronautics and Space Administration

A RESEARCH OPPORTUNITY IN TRANSPORTATION IDENTIFIED BY THE STANFORD RESEARCH INSTITUTE TECHNOLOGY APPLICATIONS TEAM SPONSORED BY NASA'S TECHNOLOGY UTILIZATION OFFICE

SENSING, CONTROL AND DIAGNOSTIC SYSTEMS FOR HEAVY-DUTY TRUCKS

T-37
July 1975

KEY WORDS

Automotive diagnostic systems, microprocessors, data acquisition, data recording, status readouts and displays, automotive electrical systems, transducers for temperature, pressure, strain, flow, torque, fluid level, etc.

APPLICATIONS

On-board and service-center based diagnostic systems, on-board indicators, warning and control systems, operations and maintenance data acquisition systems.

BACKGROUND

To improve the safety, reliability and operating economy of heavy-duty trucks, manufacturers are considering electronic system elements as additions or replacements for existing mechanical or fluidic elements, particularly sensors including those listed above. Inexpensive, reliable transducers will be required as inputs for the types of systems mentioned. There are several potential advantages of electronic-based systems over present mechanical/electrical/fluidic systems. These are the cost reduction, increased reliability and lower maintenance effort using a single integrated control and diagnostic system as opposed to a collection of unrelated independent sensing, control and display devices. For example, a single microprocessor consisting of perhaps a few dozen integrated circuits could control fuel and air flow, based on power demand, load, speed, etc., and could replace vacuum-operated and mechanical devices which require periodic adjustments. The same processor could simultaneously monitor the outputs from various sensors, linearize them if necessary, and perform rudimentary analyses for display and warning, freeing the driver from such tasks. Additionally, selected data could be processed and recorded on a small tape cassette that could be used for operational analysis and maintenance purposes. A fully integrated system would also handle a host of additional tasks around the vehicle, such as controlling the cab environment, the anti-skid braking, speed indication, etc.

For a system to be successful in the rather harsh automotive environment, high reliability will be a must. There is a growing interest among truck manufacturers in control and diagnostic systems in general and in the family of inexpensive electrical-output sensors that such system will require in particular.

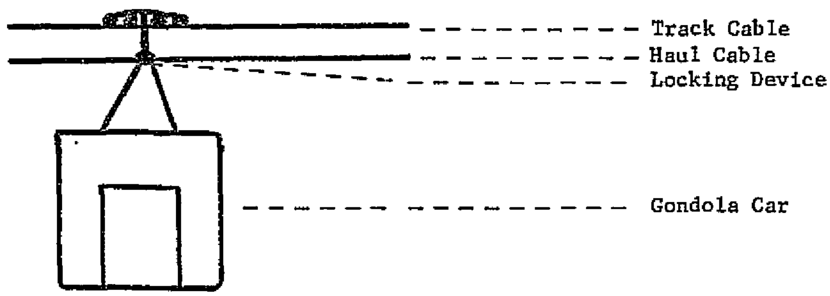
Ideas or questions on this subject may be addressed to Mr. Ken Hirschberg, NASA Tecnnology Applications Team, Stanford Research Institute, 333 Ravenswood Ave., Menlo Park, CA 94025 or to the Technology Utilization Officer at your installation.

GONDOLA CAR/CABLE MONITORING

WHAT IS NEEDED

I. Instrumentation that will monitor a gond 'a car, traveling on a bicable system (see drawing below). Sensors mus e capable of determining if gondola wheels have derailed or lost cab.-. contact or if car's attachment to the haul cable is slipping or released.

II. Instrumentation is also needed to sense excessive swaying of the car. This swaying is normally caused by high winds and can result in derailment from the track cable. If excessive sway is noted, immediate system shut down is required.



BACKGROUND

The safety of a ski-lift gondola could be greatly enhanced if each gondola car could be continuously monitored while in use. At the present time, no sensor systems are available for this purpose. Instrumentation which could sense derailment or excessive sway and then immediately shut down the system should result in greater safety for the riders of the system.

The gondola lift system consist of two steel cables, approximately 1½ inch in diameter. One of the cables, a flat surfaced, Z-lock cable, acts as the track cable; while a second cable, which has an irregular surface, acts as the haul cable--the moving member of the system. The gondola cars used have four wheels that ride on and are supported by the track cable. The wheels have hard rubber surfaces which contact the track cable to give smoother ride and reduce wear. The cars have a clamping system for attachment to the haul cable. When loading or unloading passengers, the clamping device is released from the haul cable. Approximately 50-100 cars operate on the system at the same time. Each car can carry four to eight passengers.

CONSTRAINTS AND SPECIFICATIONS

The sensor system must function in adverse climates (i.e., high mountain winter conditions). Approximately 50-100 cars must be instrumented or monitored simultaneously from a central station. Cost of the system is a factor, though not clearly identified at this time.

Ideas or questions on this subject may be addressed to Andrew Loomis, NASA Technology Applications Team, Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, CA. 94025 or to the Technology Utilization Officer at your installation.

NASA Technology Utilization Opportunity

National Aeronautics and Space Administration

A RESEARCH OPPORTUNITY IN TRANSPORTATION IDENTIFIED BY THE STANFORD RESEARCH INSTITUTE TECHNOLOGY APPLICATIONS TEAM SPONSORED BY NASA'S TECHNOLOGY UTILIZATION OFFICE

IMPROVED COOLING SYSTEM FOR TRUCKS

T-42
August 1976

NEED

An improved cooling system or new techniques for cooling internal-combustion truck engines that is quieter, requires less space and is lighter than conventional systems.

BACKGROUND

Although conventional cooling systems are presently quite adequate for engine cooling, a need for quieter systems has been expressed by a number of truck manufacturers. New regulations for truck noise emittance will come into effect on 1/1/78; this regulation will necessitate reduction of exterior noise levels to below 83dBA. The majority of truck noise above the 83dBA level is produced by a truck's cooling system (fan noise). In an attempt to reduce this noise, many manufacturers have increased radiator size to allow for slower fan speeds or have incorporated automatic fan shut-off switches. The automatic shut-off switches engage when engine/coolant temperatures are at a level permitting fan shut-down. Neither of the preceding remedies is an ideal solution to the noise problem.

Another need expressed by the industry is that of more compact-efficient cooling systems. It is anticipated that efficient space utilization will become more important in the next few years. Present cooling systems take up a considerable amount of space in the engine compartments. Lighter weight systems would also be welcomed by the industry; however, more compact or lighter weight systems are not essential to the industry at this time. If one or both were an advantage accompaning a quieter system, it would benefit the industry.

CONSTRAINTS AND SPECIFICATIONS

A new generation truck engine cooling system should be competitive in cost with conventional systems unless appreciable benefits are obtained from a new system. In that case, a higher cost might be acceptable.

Ideas or questions on this subject may be addressed to Andrew Loomis, NASA Technology Applications Team, Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, CA. 94025 or to the Technology Utilization Officer at your installation.

THIS STATEMENT CALLS YOUR ATTENTION TO A SIGNIFICANT TECHNOLOGICAL NEED IN AN IMPORTANT AREA OF CONCERN IN THE PUBLIC SECTOR. PLEASE RELATE ANY IDEAS YOU MAY HAVE TO THE TECHNOLOGY UTILIZATION OFFICER AT YOUR INSTALLATION OR TO THE TEAM REPRESENTATIVE NAMED IN THE STATEMENT

APPENDIX C

TECHNOLOGY APPLICATIONS NOTES

- Special Urban Mass Transit Edition
- Highway Issue No. 2

TECHNOLOGY APPLICATIONS NOTES

National Aeronautics and
Space Administration

NASA Technology Applications Team
Stanford Research Institute
Menlo Park, California 94025

Highway Issue No. 2
January 1977

Much of the technology developed for the space program can be applied to terrestrial transportation problems. Detailed descriptions of the technology and the test programs, as well as instructions for installation and operation, are offered by NASA's Technology Utilization Office without cost to user agencies in the public sector.

This is not a passive information service. A NASA-sponsored team at SRI matches public transportation problems with aerospace solutions in an active technology transfer program.

The status of current highway-related efforts is given below.

Highway Profile Measurement: Noncontact roadway measurement techniques have been of interest to highway and railway engineers for several years. Early attempts at road profiling utilized a test vehicle with an independently suspended fifth wheel. This wheel, linked to a stylus and recording chart, would, as it encountered irregularities along the roadway, map the surface (or profile) of the road. This method, relying on a mechanical link between wheel and recorder, was limited in sensitivity, accuracy, and dimension. The more currently used techniques employ a single-axis inertial reference such as a vertical gyro or accelerometer in conjunction with other sensors to provide vehicle roll information and/or to compensate for vehicle body motion in the measured roadway profile. This technique, though more sensitive and accurate than the contact technique, suffers from lack of dimension (i.e., measuring only roll, to the exclusion of pitch and yaw).

The NASA Technology: An Inertial Platform
Source: Marshall Space Flight Center, Huntsville, Alabama

During NASA's space program, considerable research and development effort on gyro-stabilized guidance and control systems was reported. Included in this work was the basis for an improved method of acquiring railway and highway profile measurements in three dimensions and selecting data of engineering interest. The method is based on the use of an inertial platform comprising a double-gimbal-mounted plate that is rotationally stabilized by means of three independent gyroscopes whose axes are aligned along an orthogonal coordinate system. Three integrating accelerometers, also mounted on the stabilized plate and orthogonally oriented, provide inertial reference signals to a data acquisition system. This platform, properly isolated from the test vehicle's suspension system, is the basis of NASA's road/rail profiling technique.

A prototype of the NASA platform, assembled at MSFC, will be included in the Federal Highway Administration's ongoing hydroplaning test program at Southwest Research Institute, San Antonio, Texas. The platform is being provided by NASA on a six-month loan to begin in November 1976. To provide technical assistance at the initial stages of the program, Mr. Lewis Cook of MSFC will be on site. This test will represent the first non-NASA user review of the instrumentation.

Pavement Striping for Nighttime Conditions: With the general acceptance of glass beading for traffic marking paints more than 30 years ago, the problem of nighttime delineation of roadways in dry weather was solved (as long as the beads remained intact). However, under wet nighttime conditions, the beaded paint is almost invisible. Other delineation systems with improved visibility under wet-night conditions have been developed over the years, but all have been somewhat inadequate.

The NASA Technology: A Chemiluminescent Striping Material
Source: Goddard Space Flight Center, Greenbelt, Maryland

At GSFC a novel, moisture-activated chemiluminescent formulation is being developed as a practical lig 'ing component of a highway striping material. Laboratory results have shown current formulations (oxalate ester) to be effective, though somewhat short-lived, chemiluminescent agents. Work is currently under way to extend the period of luminescence.

Ice Detection on Bridges: Patches of ice and frost on bridge decks, at a time when the approach pavements remain frost free, represent a major safety hazard in many states. Although numerous systems have been developed, and some are currently in use, no reliable scanner/sensor system is available, at an acceptable cost level, to alert motorists of bridge ice and hazardous driving conditions. Such a system probably will depend on noncontact techniques for its operation, as it has been shown that surface-mounted sensors or those embedded in the road bed, tend either to sustain a high rate of damage or to retain moisture, thereby causing fraudulent readings.

The NASA Technology: A New Device Combining an Infrared Sensor and a Dewpoint Hygrometer
Source: Ames Research Center, Moffett Field, California

An infrared detector, developed at ARC for use in remote sensing of temperatures on the planet Venus, is being combined with a dewpoint hygrometer to provide an instrument capable of accurately predicting icing conditions. This instrumentation package will be assembled to allow attachment to bridge railings or similar supports. Costs of the finished system are estimated at half those for the embedded sensors now commercially available. Testing in an environmental chamber is currently underway; field testing will follow.

Corrosion Protection of Steel Structures: Most current anticorrosion coatings for bridges and other structures consist of zinc or aluminum dust that is mixed with and suspended in an organic or inorganic binder during application. Preparation of the final coating formulation is done on site and is somewhat complex. Rising labor costs have induced the transportation industry to seek a longer-lasting, more easily applicable protective coating.

The NASA Technology: A Zinc-Rich Coating in an Inorganic Binder
Source: Goddard Space Flight Center, Greenbelt, Maryland

A search of relevant NASA literature revealed that a zinc-rich coating utilizing a potassium silicate binder, developed at GSFC and reported in NASA TSP 70-10060, may provide suitable corrosion protection. Under laboratory conditions, this water-base GSFC coating has demonstrated longer life and superior adhesion characteristics when compared to most commercially available zinc-rich inorganics, and unlike these systems, it is especially easy to mix and requires no straining before application. The product promises to provide savings in labor hours as well as material costs.

The NASA coating is currently under test on several coastal structures, on road equipment in the northeastern United States (as undercoating to protect against deicing salts), and on other specific structures exposed to high-corrosion conditions. Non-exclusive patent licenses have been issued to two paint manufacturers who are currently testing the new NASA material in-house. Commercial sale of the material is expected within the current year.

Crash Barrier for Abutments: Visits by the SRI Team to State Highway Departments have revealed a significant national safety problem. A new design of crash barriers for highway abutments is needed to ensure driver safety. This new crash barrier should be capable of providing protection against impact damage and rebound by slowing the vehicle in an incremental fashion, bringing it to a controlled stop. Many of the currently installed barrier systems are as unyielding and dangerous to the driver and vehicle as the abutments and retaining walls they protect.

The NASA Technology: Crushable Barrier Systems
Source: Jet Propulsion Laboratory, Pasadena, California

The crushable system developed by NASA (Tech Brief 72-10712) was selected by the SRI Team as a possible solution to this problem. The system comprises a large number of contiguous cylinders (cans) that are arranged in multiple strata and held in place by metal cloth. When impacted by a moving object such as an automobile, the cans are expected to slow the object by sequentially crushing, thereby dissipating the impact force in a controlled manner and bringing the vehicle slowly to rest. A prototype, fabricated at JPL was laboratory tested successfully in 1976.

A NASA Technical Memorandum has been prepared documenting the laboratory test at JPL on its modular can crash barrier. The tests indicate that this barrier results in slower and smoother deceleration than other systems. Arrangements for field testing following the procedure given in NCHRP Report No. 153, are now being made.

Because recycled aluminum beverage cans are the primary component, the system promises to be attractive to environmentalists, as well as cost effective.

Highway Skid Tester: Skidding is a major contributor to traffic accidents, and the importance of skid resistance measurement is acknowledged by the highway departments. In fact, the Highway Safety Act of 1968 states that "every state in cooperation with county and local governments shall have a program for resurfacing. . . sections of streets and highways with low skid resistance." To prove adequate skid resistance, accurate measurements of existing road surface conditions must first be made. Skid Testers are commercially available from a number of sources. However, the high cost of these units, ranging from $40,000 to almost $200,000, prevents counties, cities, and even some states from purchasing the test equipment. Therefore, in many parts of the country, only major highways are tested for skid resistance.

The NASA Technology: An Instrumented Diagonally Braked Vehicle
Source: Langley Research Center, Langley, Virginia

A pulsed braking technique employing a diagonally braked vehicle to measure the skid resistance of runways has been developed by Messrs. Walter Horne and Everett Browne at LRC. The vehicle used was a Ford Fairlane Tudor sedan with a fifth wheel for monitoring distance and velocity plus instrumentation for measuring the angular velocity of the fifth wheel. The vehicle was equipped with ASTM-E501 test tires that cost about $85 each, valves for each wheel costing about $30 each, and two different test systems--one using an inexpensive Tapley meter costing about $100 and the other using longitudinal accelerometers plus a 2-channel chart recorder at a cost of about $2,300. Thus, the total cost for the Tapley meter system (exclusive of test tires) is about $220 and that of the accelerometer system, about $2,420. Total estimated overall cost for the vehicle plus instrumentation is less than $10,000. In-house instrumentation of an existing vehicle could be accomplished for less than $500 for the Tapley meter system.

On April 13 and 14, 1976, the LRC diagonally braked vehicle and pulsed braking technique were track tested at the Texas Transportation Institute (TTI), near Houston, Texas. Skid resistance measurements were taken on seven different road surfaces and compared with those recorded by FHWA's new ARSMS skid test trailer, which was made available for the study. Fifteen test runs were made on each of the seven surfaces--five at 20 mph, five at 40 mph, and five at 60 mph.

Preliminary results obtained from the study show a promising correlation between the DBV (pulse braking) Tapley meter and the ARSMS skid trailer methods of test. This is especially true for the 20- to 40-mph speed range where a correlation coefficient of 0.994 was achieved between the DBV Tapley meter and the skid trailer. Over the 20- to 60-mph test speed range, the correlation achieved was somewhat lower, at 0.981. This reduced correlation at 60 mph is attributed to the skid trailer's pavement-wetting technique not wetting the pavement surface sufficiently at the 60-mph speed.

The experimental data for the ARSMS skid trailer and the DBV Tapley meter obtained from the study indicate that the measurements obtained by the two test methods are almost the same.

The diagonal braked vehicle equipped with a Tapley meter appears to provide accurate measurements at minimal cost. In addition, use of the longitudinal accelerometers provides direct correlation with skid trailer measurements so that no correlation equation is needed.

Soil Moisture Analysis for Highway Construction: Public works and highway departments have an immediate need for a rapid, accurate, and inexpensive technique for measuring soil moisture prior to road construction. Proper compaction of the road bed, to prevent road collapse, depends on accurate moisture measurements. Current techniques are either slow (overnight drying in an oven) or can handle only very small samples. Because most soil samples are heterogeneous and may contain large agglomerated particles, small sample measurements are inaccurate.

The NASA Technology: Gas Chromatographic Moisture Analysis
Source: Ames Research Center, Moffett Field, California

A simple and rapid analytical technique for the analysis of moisture content of soils has been developed as part of the Viking and post-Viking studies at ARC. This technique entails extraction of moisture from a soil sample by means of a solvent that is subsequently analyzed with an inexpensive dedicated gas chromatograph.

A portable unit for on-site use is envisioned that will enable soil analysis in less than an hour. Work is currently under way to build a model for field testing. Initial tests will be conducted by Santa Clara County (California) public works personnel, with tentative plans made for the FHWA Fairbank Research Station in McLean, Virginia, also to evaluate the technique. Should the technique be capable of handling large samples, as currently seems likely, the FHWA will prepare appropriate information for dissemination to all state highway departments.

Fire-Resistant Materials: For increased passenger safety in case of fire in a public transit car, especially in the confines of a tunnel, construction materials need to be more fire resistant than those now used. Improved materials are sought for cable insulation, thermal and acoustic insulation, wall and ceiling panels, floor covering and carpeting, seat cushions, and seat covers.

The NASA Technology: Fire-Resistant Materials

Source: All NASA Centers

NASA has developed or funded the development of several nonmetallic materials and formulations that meet the flammability and toxicity requirements for spacecraft use. These materials are now occasionally used in the public and private sectors in cases where weight and flammability considerations remain of high importance and cost is less of a consideration (such as in aircraft, especially military aircraft). The high-volume usage projected for rapid transit applications alone, for example, requires a significantly more inexpensive material if commercialization is to occur.

Scientists at NASA's Johnson Space Center are involved in a program designed to combine technology of less expensive conventional materials with that of more expensive fire-resistant aerospace materials to develop cost-effective fire-resistant materials for aircraft passenger compartments. The results should also be applicable to rapid transit cars and buses.

Researchers at the Jet Propulson Laboratory are developing and testing polymeric materials (for structural and nonstructural applications) made fire-resistant by the addition of substantial quantities of inorganic fillers and additives. When these materials are exposed to high temperatures, the filler components generate large amounts of nontoxic gases (such as water and carbon dioxide) to dilute the flammable and toxic combustion products and thus inhibit flame spread. Although the materials are promising, they require additional testing to prove their utility in passenger vehicle construction. Scientists at JPL have installed an NBS Smoke Chamber and a Limiting Oxygen Index Testing Setup and are currently testing the smoke and flammability characteristics of various combinations of inorganic fillers and base polymers Results up to September 1976 are detailed in the JPL progress report "Fire and Smoke Retardant Materials for Mass Transit Vehicles." Tests indicated that the best smoke retardants are $Na_2SiO_39H_20$, $Mg (SO_4) . 7H_20$, and $Mg(OH)_2.CaCO_2$ in a polyurethane also shows much promise. When it is confirmed that an elastomer can be prepared that is fire resistant and generates very little smoke, further work will be done to improve mechanical properties, primarily by methods developed in past solid propellant work. The initial application planned is the development of a low smoke, flame, and toxicity, electric cable jacket.

For additional information on any of these activities or other problem areas, please contact Mrs. Ruth M. Lizak, Team Leader, Highways, SRI's NASA Technology Applications Team, Menlo Park, California, (415) 362-6200 ex. 3778.

TECHNOLOGY APPLICATIONS NOTES

NASA Technology Applications Team
Stanford Research Institute
Menlo Park, California 94025

SPECIAL URBAN MASS TRANSIT ISSUE
April 1975

An active effort is being made by the National Aeronautics and Space Administration's Technology Utilization Office to transfer technology from the U.S. aerospace program. One aspect of this effort matches problems in the public sector with solutions in the aerospace knowledge bank. A Technology Applications Team performs this function at several interdisciplinary research institutes by interacting with public-sector people who can define the problems and with NASA scientists and engineers who can bring technology to bear on the problems.

One such activity takes place at Stanford Research Institute (SRI), where a NASA sponsored team has operated for more than four years. Its primary objective is to transfer technology from the aerospace bank to help solve problems in the many fields of transportation. Coupled with this mission is the development and application of methodology to achieve such transfer, particularly in ways to decrease the time gap between the development and marketing of new technology. In this way, the Team is able to aid the movement of knowledge across industrial, disciplinary, and regional boundaries.

The SRI Team's transportation activities have brought about interaction in the areas of mass transit (rail rapid and bus), railways, highways, waterways, and trucking. In the mass transit area, the Team interacts with the Department of Transportation's Urban Mass Transportation Administration and Transportation Systems Center, the Transit Development Corporation, and the individual transit authorities.

The purpose of these Technology Applications Notes is to inform you of some of the mass transit problem areas currently under investigation. A brief problem definition is given, followed by a summary of applicable NASA technology and the status of adapting it toward the problem's solution.

Improved Fire Resistant Materials for Transit Vehicle Construction: For increased passenger safety in case of fire in a rapid transit car, especially in the confines of a tunnel, construction materials need to be more fire resistant than those now used. Improved materials are sought for thermal and acoustic insulation, wall and ceiling panels, floor covering and carpeting, seat cushions, and seat covers.

NASA and the SRI Team are initiating a study to determine what advanced aerospace materials may be used in mass transit vehicles for increased fire safety. For example, NASA scientists are currently combining less expensive conventional materials with the more expensive fire resistant aerospace materials to develop cost-effective fire resistant material composites for aircraft passenger compartments. The results should also be directly applicable to rapid transit cars and buses.

NASA researchers are also developing and testing polymeric materials (for structural and nonstructural applications) made fire resistant by the addition of substantial quantities of inorganic fillers and additives. When these materials are exposed to a high temperature, the filler components generate large amounts of nontoxic gases (such as water and carbon dioxide) to dilute the flammable and toxic combustion products and thus inhibits flame spread. Although promising, the materials required additional testing to prove feasibility for use in passenger vehicle construction.

Increased Systems Assurance for Complex Transit Systems: An increased use of automation is occurring in the new and expanding fixed guideway transit systems (e.g., rail rapid and personal rapid transit) with the addition of such subsystems as automatic train control. The addition of automation to an already complex transit system can lead to more frequent failures, more maintenance, and less system availability. To overcome these problems, the elements of systems assurance (e.g., quality assurance, reliability, maintainability, system safety and security, and system life cycle cost) must be designed and integrated into the overall transit system. To achieve this, improved engineering systems assurance technology and management methodologies for the transit industry are needed.

Most of today's systems assurance technology was originated and developed by the aerospace and defense industry. NASA's expertise in the applications and integration of systems assurance has led to the successful completion of many large complex projects, such as the Apollo Project. For the transit industry's benefit, NASA engineers have initiated a project for DoT's Transportation Systems Center to determine and outline those elements of its quality assurance experience that are suitable for use by the transit industry.

In addition, NASA has combined applicable NASA Apollo safety management techniques (i.e., hazard identification, elimination or reduction of risks, follow-up and risk control, decision by management to accept risks, responsibility of regulatory agencies and the owner and his agents, cost effectiveness, and application to national goals) to develop a risk management system (RMS). The risk management system is a safety management methodology that will allow regulatory agencies on the local, state, and federal level and the owners and operators of potentially hazardous facilities to systematically identify hazards and reduce risks to an acceptable level of protection. NASA is currently adapting this RMS for use in certification of liquid natural gas facilities in New York City.

The SRI Team believes that this basic RMS methodology, incorporated with all the systems assurance elements and tailored to the rapid transit industry, will be of real value.

Increased Energy Storage Battery for Electric Vehicles: Because of the air and noise pollution caused by internal combustion engines, the idea of battery powered electric vehicles is becoming increasingly popular. The U.S. Postal Service has experimented with electric vehicles for some time, and recently the transit industry began testing electric buses. However, currently available lead-acid batteries supply only 10 to 15 watt-hour/lb, which is much less energy per pound weight than diesel fuel. Improved batteries are therefore needed for electric vehicles.

For space applications, NASA has been working for more than a decade to develop long-life batteries with more energy per pound of battery weight. The two most significant developments are a greatly improved zinc anode and an inorganic separator element. These developments helped lead to a three to fourfold increase in the life of silver-zinc batteries for space use. Although silver is too scarce for widespread use in batteries for earth applications, the same separator technology is being applied to the development of nickel-zinc batteries that promise to store more than twice the amount of energy per pound as the present lead-acid batteries.

Electric Cable Coating for Reduced Smoke and Toxicity in a Fire: The need for a coating for existing electric cables or new cable construction materials that produce minimum smoke and toxic gases when exposed to fire has become apparent in the rapid transit industry in the past few years. The need is especially important in closed locations, such as in cars and in tunnels. The blinding smoke and toxic gases evolved in such situations can pose a greater threat to passengers than the fire itself.

NASA has used several commercially available nonmetallic materials that meet the flammability and toxicity requirements for spacecraft use, but their high cost precludes use in the large volume required for cables in rail rapid transit tunnels. NASA scientists are working with the SRI Team on this problem, however, relating it to efforts under way on fireproof materials of construction.

Technology Transfers to Other Areas: Some of the NASA technology being transferred into the railways, highways, trucking, and waterways areas may also be useful to urban mass transportation. Reports on some of the currently active problems follow.

- Stress measurement in rails and wheels. Detection of locked-in stresses can help reduce train derailments. Feasibility has been demonstrated for applying a NASA developed ultrasonic technique to the measurement of residual stress in rail and wheel rim segments.

- Railway/highway profile measurement. A NASA developed inertial platform is being adapted for use as an inertial reference for roadway profiling. The advantages of the platform over simpler references are improved accuracy and a capability for measuring the very long wavelength components of a profile.

- Improved brake lining material. New materials for brake linings are needed for trucks, buses, and postal vehicles to increase wear and safety. One such material was developed by NASA in a reformulated airplane friction material developed for SST brakes. Experimental brake linings are now being developed preparatory to road testing.

- Bridge failure detection. Technology is sought to aid bridge inspectors in detecting cracks not detectable by routine visual inspection. A NASA technique called Randomdec, which monitors a structure's random vibration signatures, is currently being evaluated in field tests.

For additional information on any of these problem areas, please contact the Team members listed below. If your problem areas differ from those listed here, we invite you to discuss them with us. The SRI Team's activities are only partially represented here. Interaction on numerous other highway, rail, rapid transit, trucking, and waterways problems is constantly under way. It is indeed possible that we may have already considered the problem you are facing and may have uncovered a solution for it. We look forward to hearing from you.

Dr. Tom Anyos, Director
Mr. James P. Wilhelm, Team Leader, Mass Transit and Railways
Mrs. Ruth Lizak, Team Leader, Highways
Mr. Kenneth Hirschberg, Team Leader, Motor Vehicles

APPENDIX D

EXECUTIVE SUMMARIES OF MARKET SURVEYS

MARKET SURVEYS

In an attempt to stimulate early user involvement in the technology transfer process, the SRI Team has offered potential users brief surveys illustrating the market potential of specific products based on NASA technology. Market studies completed during this reporting period included:

"Zinc-Rich Coatings," by Ruth M. Lizak

"Brake-Friction Materials," by James P. Wilhelm and Andrew V. Loomis

"Highway Skid Tester," by Ruth M. Lizak

The executive summary of each report appears in this appendix. The full report can be obtained from NASA Technology Utilization Office, Code KT, Washington, D.C. 20546

ZINC-RICH COATINGS

EXECUTIVE SUMMARY

Coastal bridges require more corrosion protection than inland bridges because of their exposure to salt spray/fog. Painting the bridges at frequent intervals has been the usual (very costly) remedy.

Zinc-rich coatings with both organic and inorganic binders have been considered. Inorganics give longer protection and may be applied without a finish coat; however, those currently available are harder to apply than organics.

NASA's potassium silicate/zinc-dust coating (Tech Brief 70-10600) appears to provide longer protection, resist thermal shock, and overcome the application problems. The water-base binder sprays easily, adheres readily, and can be heavily loaded with zinc particles to provide uniform coverage. Panels coated with the NASA formulation withstood 5308 hours in the California Department of Transportation salt spray chamber with no rusting or blishtering. The formulation selected for the test was:

	Percent by Weight
Potassium silicate solution	17.6
Methyltrimethoxysilane	0.4
Zinc dust, 325 mesh	82.0

The Golden Gate Bridge Authority will field test the NASA formulation in early 1975 by applying it to a girder of the famous bridge. Of particular interest to maintenance personnel will be its ease of application.

Material costs are estimated at $9.24 per gallon. Other production costs including labor and overhead are estimated at $2.60 per gallon, for a total of $11.84 per gallon. With a 45% gross profit, not uncommon in the paint industry, the price could be $22.50 per gallon. Current prices for commercially available zinc-rich coatings range from $14.40 to $43.84. Initial costs for establishing a small operation that could deliver 5000 gallons of coating could be as low as $62,000.

A market size in excess of $2 billion is available currently for highway bridges, utility pipelines, nuclear reactors, and railcar hoppers alone. Other markets include off-shore drilling facilities, railroad bridges, and the shipping industry.

The NASA coating faces competition from established brands. Entering the market would be facilitated if the manufacturer already had some channels of distribution.

U. S. Patent No. 3,620,784 has been granted to NASA for its potassium silicate/zinc-dust coating. Patent rights may be licensed through the Patent Counsel of Goddard Space Flight Center, Code 204, Greenbelt, Maryland 20771. Exclusive rights may be considered.

BRAKE FRICTION MATERIALS

EXECUTIVE SUMMARY

A composition material developed by National Aeronautics and Space Administration (NASA) may be useful as an improved vehicle brake friction material. To assist NASA in identifying a potential market for this material, the SRI Technology Applications Team has conducted a survey of the market for vehicle brake friction materials in the United States.

The purpose of this market survey is to outline the technical and economic requirements that a candidate composition friction material must meet before it can be considered a viable product. In addition, we have reviewed the properties of composition brake friction materials currently on the market to identify those properties that, if improved, would be a useful advance to the product. Consequently, any new material that possesses any of these improvements may have a competitive advantage over currently available materials.

The brake friction material developed by scientists at NASA's Ames Research Center exhibits an essentially constant coefficient of friction with temperatures ranging as high as $650^{\circ}F$ and an average coefficient of friction of approximately 0.34. A comparison of the change in coefficient of friction versus temperature for the NASA material and conventional brake lining materials demonstrates the superiority of the NASA material at temperatures greater than $400^{\circ}F$. At these higher operating temperatures the NASA material's coefficient of friction actually increases while that of conventional brake linings decreases markedly. Wear improvement at elevated temperatures has also been noted.

Considering the market, based on the data gathered during the course of this survey, the bus-brake market appears to have the highest potential for the successful entry of a new brake friction material. Such a material would need to exhibit the following improvements over conventional linings:

- Reduced noise during braking
- Reduced fade, more stable coefficient of friction at elevated temperatures.
- Reduced lining wear
- Reduced drum wear
- Either comparable in price to conventional linings or exhibiting no more than a 40% increase.

Market size is estimated at 750,000 to 800,000 pieces per year (original equipment) and as high as 8.0-8.2 million pieces per year (after-market). This represents a yearly market of $22-27 million.

The market chosen as the second most favorable for the penetration of a new friction material is the heavy truck brake lining market. Rising labor costs and increased federal legislation have increased the industry's awareness of its need for such new materials.

The original equipment market for truck linings in 1975 is estimated to be approximately 8.0-8.5 million brake blocks at a market value of $20-21.3 million. An additional 1.46 to 1.49 million pieces at a value of $3.65 million to $3.75 million will be sold for use on new trailers manufacturers in 1975.

The after-market for trucks and trailers is estimated at 9.50 to 10.25 million brake blocks at a value of $23.8 to $25.6 million.

Although a considerably more detailed study than was possible in this survey is necessary to accurately determine the size of the market, it appears that improved brake friction materials are also needed in the industrial equipment sector. This category includes equipment such as overhead cranes, hoists and the like and represents an overall brake-lining market value estimated at $80-100 million annually.

Other areas studied include passenger cars, light trucks, heavy trucks and truck/trailers, rail cars and light aircraft. Estimates of the current brake lining market for these sectors are given below:

Vehicle Type	Market	Volume Pieces/ Year (000)
Passenger Cars	Original Equipment	72,000-73,000
Passenger Cars	After-Market	210,000-220,000
Light Trucks	Original Equipment	16,000-18,000
Light Trucks	After-Market	22,000-24,000
Trucks	Original Equipment	8,000-8,500
Trucks	After-Market	4,000-4,250
Trailers	Original Equipment	1,460-1,490
Trailers	After-Market	5,500-6,000
Buses	Original Equipment	750-800
Buses	After-Market	8,000-8,200
Rail Cars	-	3,290
Light Aircraft	-	600

Market entry into these sectors is strongly limited by lining cost (i.e., a very strong technical advance over current materials would be required to justify any additional lining cost). For this reason, and our belief that the NASA material does not exhibit these advances, we do not anticipate market penetration in these areas.

In summary, it appears that the NASA Ames brake friction material will gain its easiest market entry in the bus, truck and industrial equipment brake sectors. To insure this penetration the NASA material, once released, must exhibit a more stable coefficient of friction at elevated stable temperatures than conventional materials, must show some wear improvement over conventional materials and will have to be at best cost competitive or at least, cost effective.

HIGHWAY SKID TESTERS

EXECUTIVE SUMMARY

A primary cause of highway accidents is insufficient tire-pavement friction on surfaces that are unevenly textured, undulating, or wet. Tire-pavement friction as it relates to wet-weather skidding has been a concern of highway officials for some time, and almost all states have begun programs to test their highways for skid resistance qualities. The United States has a network of 3.8 million linear miles of paved roads.

Skid resistance is measured with the aid of a skid tester, which is an automotive vehicle having one or more test wheels, torque or force transducers, a signal conditioning and recording system, and actuation controls for braking the test wheel. Currently available skid testers consist of a towing vehicle with a trailer that houses the test wheels. These testers, which range in price from about $30,000 to more than $100,000 depending on size and instrumentation, may be cost-effective for testing primary highways; however, for testing secondary roadways and responding to calls to check accident locations, a smaller model with minimal instrumentation may be more advantageous.

An inexpensive single-unit Diagonal-Braked Vehicle, developed by the National Aeronautics and Space Administration (NASA) for testing runways, can be operated at highway speeds by applying a pulsed braking technique. With diagonal braking, one (unlocked) front wheel is always available for steering and its diagonally opposite rear wheel is free to maintain vehicle lateral stability. In tests conducted by NASA, the diagonal braking test method showed very good correlation with the skid trailer method. At a cost of less than $10,000, the NASA vehicle provides accurate skid testing, taking both longitudianl and lateral measurements.

A recent survey of all 50 state highway departments indicated that only 81 skid trailers are currently in operation and that an immediate market would exist for 249 additional testers if a tester were available for under $10,000. For a widespread program to test all roadways, another 3026 testers might be needed.

December 1974

EXECUTIVE SUMMARY

SYSTEMS ASSURANCE

Background

With the growing need for urban public transportation in the United States, significant construction and expansion of rail rapid transit systems is planned. Three transit authorities are expanding, one new transit property was recently completed, three new transit systems are under construction, and seventeen cities are considering construction of a fixed rail system.

An increased use of automation is expected in the new and expanding transit systems. Although automation requires a high initial equipment cost, a significant cost benefit results from a reduction of the recurring costs of manual operation. The specific expected advantages of automation include increased safety, reduced operating costs, increased passenger comfort, increased system train capacity, reduced service disruptions, and improved maintenance coordination.

The increased use of automation is occuring primarily in the automatic train control subsystem. Automatic train control (ATC) includes automatic train protection (performs train and track surveillance, train separation and interlocking, and overspeed protection), automatic train operation (performs on-board velocity regulation, stopping, door operation, and starting), automatic train supervision (performs centralized train scheduling and operational implementation, yard train control, ATC system maintenance management, and overall system maintenance management), and communication systems (performs data and voice communications to unify and support all other elements of ATC).

The addition of a complicated ATC subsystem to an already complex transit system can lead to more frequent failures, more maintenance, and less system availability. Car availability for one transit system has been as low as 60%, when 90% or better is needed to provide the desired service.

In addition to designing a system fail-safe, a system must also be fail-operational and safe with an initial failure and fail-safe with any subsequent failures. To achieve this goal and to overcome these problems, the elements of systems assurance (e.g., quality assurance, reliability, maintainability, system availability, system safety and security, and system life cycle cost) must be designed and integrated into the overall transit system. Subsystems of the overall transit system include vehicles, ATC, auxiliary systems, rail and right-of-way, civil structures, operational procedures, personnel, and management. Therefore, system design, test, evaluation, and management methodologies and experience are needed for the complicated process of new system planning, specification, source selection, contract management, systems integration, first article testing, and system testing.

Problem

To achieve desired system availability, reliability, safety, and maintainability goals, there is a need for improved:

- systematic utilization of the systems engineering methodologies of
  - quality assurance
  - reliability
  - maintainability

- system availability

- system safety and security

- system life cycle cost

- overall management and systems engineering methodologies to assure

  - the coordinated utilization of the methodologies of each element of systems assurance from the smallest part (by the vendor) to the component (by the subcontractor) to the subsystem (by the prime contractor) to the total system (by the transit authority).

  - the compatible integration of all the elements of systems assurance

  - the coordinated utilization and compatible integration of each of the elements of systems assurance from the initial planning stages to the operational stage and later expansion stages of a transit system.

Proposed Solution

Most of today's systems assurance technology was originated and developed by the aerospace and defense industry. NASA's expertise in the application and integration of systems assurance has led to the successful completion of many large complex projects (e.g., the Apollo Project). Therefore, it is suggested that a NASA Technology Utilization Program be initiated toward the application of NASA's systems assurance and management technology to the U. S. rail rapid transit industry.

To effect this technology transfer, it is suggested that a group of systems engineering and management experts from the transit industry and NASA, or key NASA contractors, be formed to:

(1) Conduct a rail rapid transit industry state-of-the-art appraisal of

  - systems engineering methodologies

  - project management methodologies

(2) Adapt applicable NASA systems assurance systems engineering and project management methodologies to the rail rapid transit industry.

(3) Write a transit industry systems assurance guideline document.

(4) Estimate the cost/benefit return to the industry with the implementation of these systems assurance methodologies.

(5) Recommend methods to assure the best utilization of this technology by the transit industry (e.g., seminars and on-the-job training).

The products of this effort can be used by management and engineering personnel of DoT's Urban Mass Transportation Administration, individual transit authorities, project sponsors, and state and local regulatory bodies in applying the systems assurance methodologies during the construction or extension of a rail rapid transit system. Alternate versions of the systems assurance methodologies can also be developed for other transit systems, e.g., personal rapid transit and light rail vehicles (streetcars).

In summary, the adaption of applicable aerospace systems assurance technology to the transit industry will lead to increased service and reduced operating costs for a transit system.

Questions or Comments Should Be Directed To:

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APPENDIX E

Excerpts from Shaker
Corporation Report

Excerpts from "Investigation of a Bearing Fault Detector for Railroad Bearings," by Donald S. Wilson, John L. Frarey, Shaker Research Corporation, Ballston Lake, New York.

Fault Detector Prototype

The block diagram for the engineering model fault detector is shown in Figure E-1. Four sets of data are shown that characterize the signal at four different points in the circuit and also relate to examples of data processing previously discussed. Three of these sets show both the frequency and time domain signals while the output of band pass filter B is an almost pure tone shown only in the time domain.

The block diagram as shown in Figure 10 is the most versitile. Data obtained to date indicates that possibly not all blocks would be required in the final unit and that some controls and outputs could be eliminated to simplify the operation; however, for the present program, the maximum sensitivity shown was retained. The example of the processed data in Figure 10 is for the switch portion shown. The description of the block diagram follows:

There are two inputs to the unit--one labeled accelerometer input and one voltage input.

When the fault detector is used on a bearing in real time, the accelerometer mounted to the bearing is connected to the charge amplifier which conditions the data (removes effect of cable capacitance) and normalizes it to take into account different accelerometer sensitivities. If magnetic recordings of data obtained during bearing tests are made, this type of data is played back into the volt input and bypasses the charge amplifier. In the next stage of the unit, a high pass filter may be inserted or bypassed. Because the sound and acceleration data contains high level low-frequency components, the filter was used for the testing to permit the greatest possible dynamic

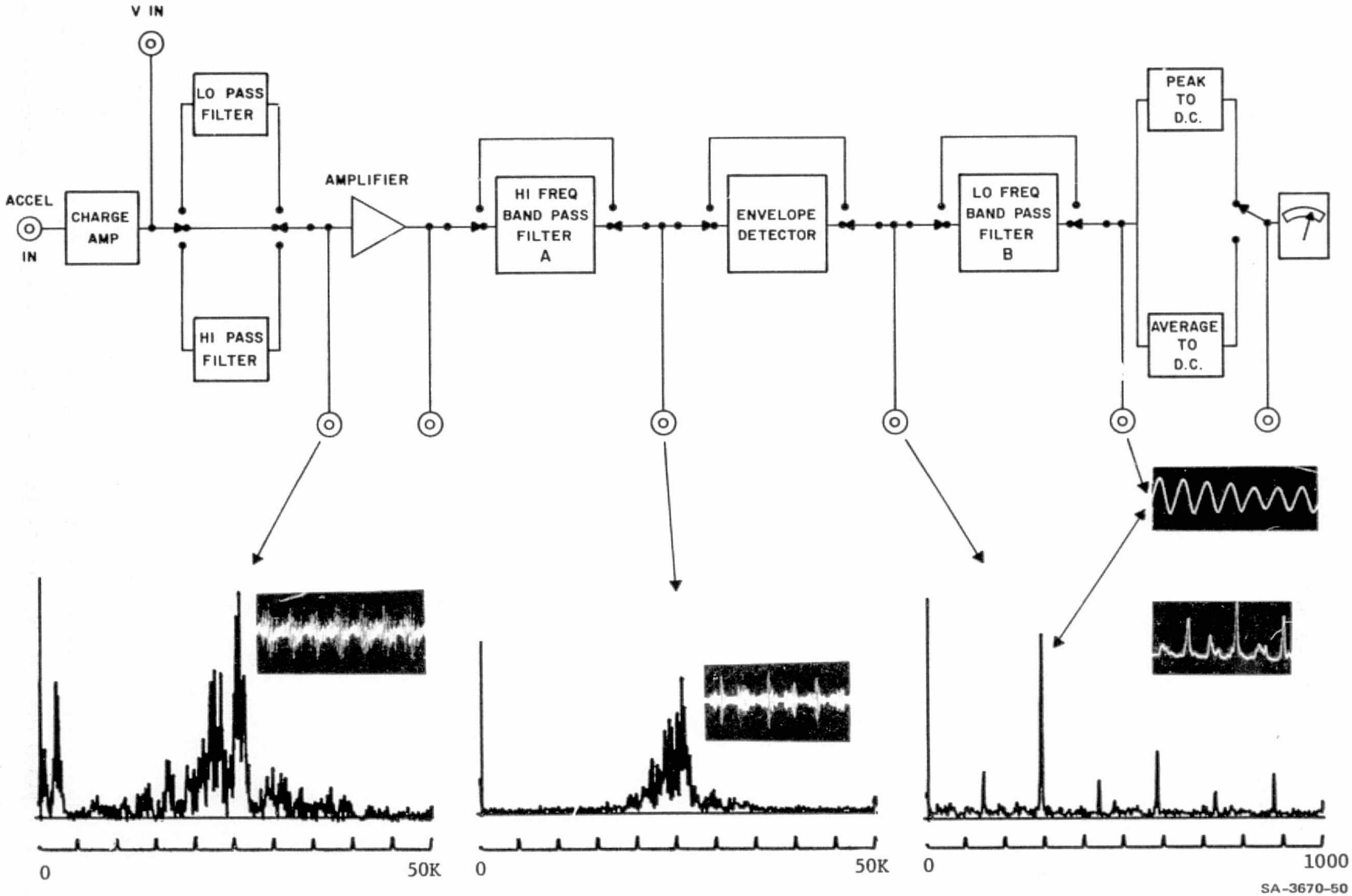

FIGURE E-1 FAULT DETECTOR BOX

range of high-frequency data.

Following the high pass filter is a step amplifier to ensure adequate signal level for filtering and demodulating. Figure 10 illustrates a frequency spectrum of the high passed data accompanied by a picture of the raw data following the amplifier. The signal passes from the amplifier to a tunable high pass filter. The filtered data at a center frequency of 22 kHz is illustrated with a frequency spectrum of the frequency content of the filtered wave. The amplitude envelope of the 22 kHz frequency is detected through a demodulator. The envelope and its frequency spectra showing roller pass frequency are also shown in Figure 10. The low pass tunable filter was used to pass the roller pass frequency to check its amplitude.

A selectable peak and average reading meter was used to visually observe the peak amplitudes of the high-frequency bandpassed data and and the demodulated low pass roller frequency to check its amplitude.

The fault detector box has two tunable filters that were considered necessary since it was not certain that the same frequencies observed in the laboratory would be encountered in the field. Ultimately a box for field use could contain fixed filters and warning lights to indicate good or bad bearings. This, however, requires verification of the frequencies and amplitude levels as encountered in the field.

SUMMARY

Laboratory tests on fifty seven bearings ranging from new to various degrees of damage indicated that structure-borne vibration in the 14 KHz to 20 KHz and 20 KHz to 30 KHz ranges could be used to discriminate between new and damaged bearings. Airborne sound in the same frequency ranges could also be utilized to categorize bearings but did not prove as discriminating as structure-borne acceleration. Demodulation of both 16 KHz and 22 KHz center frequencies permitted analysis of discrete bearing running frequencies for identification of the fault. The primary frequency observed was roller pass frequency.

A fault detector box breadboard was assembled to permit band pass filtering and demodulation of the frequencies of interest. The box was used for field testing of fully-assembled grease packed bearings.

Field testing of several damaged and new bearings were conducted on a grease test machine located at the AAR in Chicago. Acceleration and sound were recorded on the rig that accepted a complete axle assembly over an equivalent train speed range of 60 mph to standstill. High amplitude vibration was observed from the acceleration level in the 10 KHz and 17 KHz ranges. These frequencies were found to be driven to the high amplitudes by roller pass frequencies of damaged bearings. Below speeds of 25 mph, discrimination between good bearings and damaged bearings was difficult. With axles assembled on a truck and pushed at speeds below 5 mph, discrimination of damaged bearings could not be made.

The field tests on the grease test machine basically confirmed the data obtained in laboratory tests. The suitable ranges for detecting bearing damage differed in the field tests from 10 KHz and 17 KHz compared to 16 KHz and 22 KHz in the laboratory. However, the trends of amplitude followed the laboratory tests for good versus bad bearing.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn based on program results:

1. The concept of utilizing high-frequency vibration and modulation characteristics to identify damage in railroad roller bearings is a valid one.

2. High-frequency characteristics in the 16 KHz to 17KHz range can be used to identify bearing faults in oil-lubricated bearings in the laboratory as well as on fully-assembled grease-packed bearings installed on axles.

3. High-frequency structure-borne vibration was more suitable than high-frequency airborne noise in identifying faulty bearings;

however, sound levels for damaged bearings were 10 db higher than good bearings.

4. Bearing speeds greater than the equivalent of 25 mph are required to adequately separate good bearings from faulty bearings when the bearings are not loaded. Field data on heavily-loaded bearings were not obtained; however, it is expected that this should reduce the test speed.

5. Inspection of bearings at a derailment site is feasible utilizing a portable drive rig to operate the unloaded bearings at approximately 30 mph.

6. Testing was concentrated on the 6 x 11 size bearing. Some testing showing equivalent results was conducted on the 6-1/2 x 12 size bearing. No tests were conducted on the 5-1/2 x 10 size bearings.

7. Although airborne noise results were promising, the feasibility of a wayside detection system utilizing either track mounted accelerometers or airborne noise cannot be assessed on the available data.

Recommendations

The following recommendations are made to further implement the high-frequency vibration technique as a means of detecting bearing faults after a car derailment without wheel disassembly:

1. Conduct additional laboratory tests on 5-1/2 x 10 and 6-1/2 x 12 bearings to insure that all three commonaly used bearings produce equivalent results and therefore a single detector system can be used.

2. Conduct initial feasibility tests on a sample of derailed bearings mounted on the axle at a railroad wheel shop. In order to accomplish this a prototype fault detector box with a fixed 17 KHz filter and a rig to rotate the bearing cup (outer race) must be fabricated. Fault detector outputs will be correlated against normal AAR approved visual inspection.

3. If the results of (2) are positive, fabricate an automated version of the prototype system for installation in a railroad wheel shop for long term testing to obtain statistically significant data.

4. The greatest economical benefit to the railroads would be to test the bearings before removal of the wheel and axle from the car at the RIP track following a derailment. A system should be designed, fabricated and tested to lift the truck and spin the wheels and axles.

The following recommendations are made to further implement the high frequency vibration as it applies to detecting defective bearings from a wayside location.

5. Conduct additional airborne noise tests from defective bearings under load at slow speeds.

6. Record and analyze data from a wayside location for several passing trains for both microphone and rail mounted accelerometers to note background noise and variations from car to car.

7. Conduct a test at a location prior to an interchange inspection yard that will allow comparing car condition to accelerometer/microphone outputs for selected cars.

NOTE: Recommendations 2, 5, and 6 are being implemented under Department of Transportation Contract DOT/TSC-917. Initial results from the rail mounted accelerometer have been encouraging.