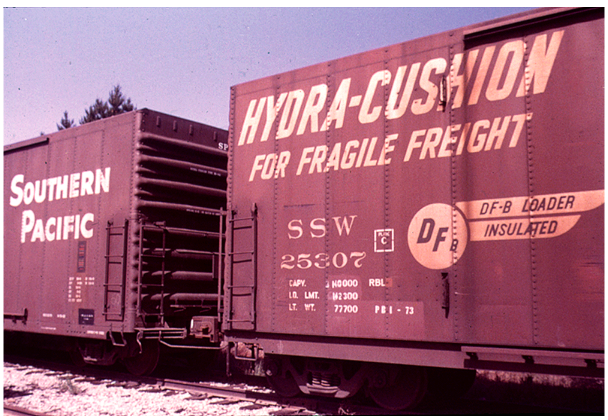
Chapter 6
Transportation

Hydra-Cushion

In the 1950s, railroad boxcars and jolts just seemed to go together. Beyond the obvious noises were the more silent problems of broken goods and broken rolling stock as well as the often hidden costs of dealing with both. Even when insurance covered such costs, the cost of the insurance itself added up. At that time, damage to rail freight shipments amounted to more than $100 million a year. Some of the railcars of the day had spring-based couplers, but they weren't very effective and an improved solution to such impacts was clearly needed. That need was augmented by the practice of forming trains by pushing them over the crest of a small hill into a "tree" of switches, a process called "humping." The down-slope speed of the railcar was 7 or 8 miles an hour and the in-rail braking systems of the hill often left a car vulnerable to impact from the car to follow. This practice of humping ensured that the jolt-at-coupling would continue.



One of SRI's long-time Board members was Don Russell, president of Southern Pacific Railroad (SP). Through Russell's awareness of the technical capabilities at SRI, the chief engineer at SP was asked to consider whether SRI might help with some of SP's more important technical challenges. Among the problems that surfaced in these discussions was the problem of high-impact coupling.

A cooperative project with the Southern Pacific began in 1954, with SRI undertaking the design of a new coupling system and the SP yards in South San Francisco doing the early, prototype fabrication. The work focused on the so-called "draft gear," a part of the coupler designed to cushion against the damaging high-energy impacts. The goal was to design an improved draft gear that was low cost, simple in construction, reliable, and maintenance-free. The new system also needed to be sensitive to the energy of the impact and to adjust the cushioning action accordingly. The SRI Hydra-Cushion was the result, and it was eagerly pressed into service in a large fraction of railroad freight cars designated to carry fragile loads.

The new impact-absorption concept was developed by William K. MacCurdy, who joined SRI in 1952 as a former naval architect with a background in shipbuilding, not railroads (see Figure 6-1). As he said, and this is important for a research environment, "the request came as a wide open question rather than a query for any specific solution…They described the industry's loss and damage problem and asked…if we could suggest any improvements in existing

Figure 6-1. SRI project leader and Hydra-Cushion designer, William MacCurdy.

practices. The Institute's practice is to examine a problem over-all so as to see where the real problems are."[A] SRI conducted a literature study and performed a survey of car-handling practices. The researchers found that cushioned underframes had been around for years but the "short travel" (the distance the coupler could move at impact) made it impossible to absorb the shocks they were experiencing. MacCurdy chose a more fundamental approach.

Ideally, the railroad car frame that supports the car and rests on the rolling trucks should not directly carry the pulling or stopping force to the adjacent cars. In the new concept, the train's load is transmitted from one coupler to the next by two sliding sills or beams whose movement is restrained by forces sensitive to their acceleration. Each coupler has an extended connection (sill) to a point in the center of the car where the Hydra-Cushion mechanism is located (Figure 6-2). The energy absorption starts with an interleaving of fingers on the end of each sill away from the coupler and some stationary fingers in the Hydra-Cushion unit. To make the restraint proportional to impact acceleration, a hydraulic piston increases the pressure on the interleaved fingers via a wedge attached to each sill.

The oil movement within the hydraulic piston is regulated in such a way that the braking effect is almost proportional to the magnitude of the impact.[B] To prove the soundness of the design, a railcar was modified in SP's Sacramento shops and quickly placed in

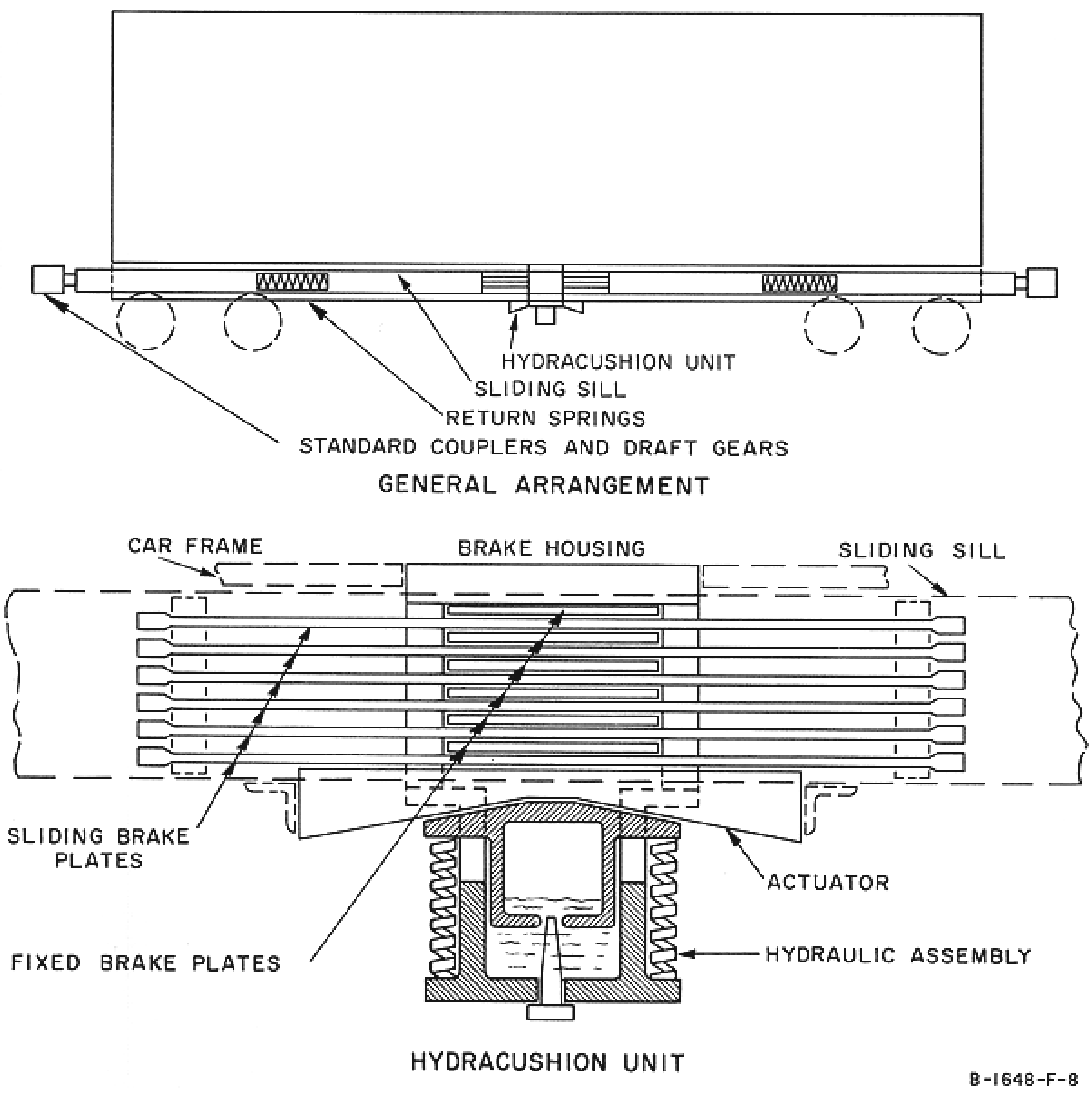


Figure 6-2. Schematic of the Hydra-Cushion unit showing its location and its operating mechanism.

service for testing in December of that year. To give it a difficult test SP first put the car into "windshield service" from Detroit to the West Coast. The result was remarkable, with absolutely no claims for the first 6 months. The unit for that car was actually called "Hydra-friction." The second model, renamed Hydra-Cushion, was completed and introduced for in-service testing of fragile goods in April of 1956.

The benefits of the MacCurdy design can clearly be seen in the comparative loading or impulse traces shown in Figure 6-3. Not only is the peak initial load on the frame much less, the recoil is non-existent! The success of these models prompted 350 cars to be built and placed in SP service during the summer of 1957.[1]

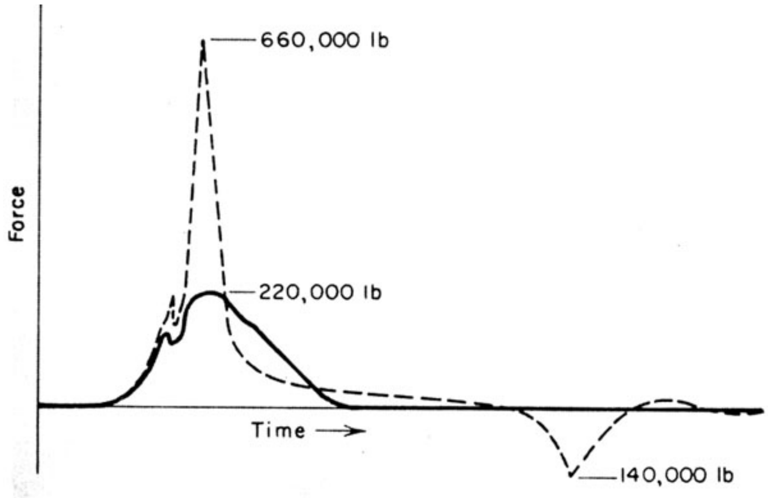


Figure 6-3. The change in the load on the under-carriage of a railcar with Hydra-Cushion given a 7-mph impact. The car was loaded to 169,000 lb.

These newly equipped cars were reserved for the more damage-susceptible loads such as canned goods, furniture, household appliances, paint, and glass. During their first year of service, the Hydra-Cushion-equipped cars made 1745 loaded trips. On 1425 of these, no damage to any goods was reported. On 445 shipments of canned goods, 70% were undamaged, whereas the rate in unmodified cars was only 48%. Most telling, however, was that the average value of the damage loss was reduced by a factor of 25.[C]

Though SRI does not show a MacCurdy patent in its database, SP gained some proprietary information on the Hydra-Cushion mechanism that it licensed in 1957. The license was to Evans Products Co. (where MacCurdy went after leaving SRI) for manufacture of the mechanism for all the railroad industry. SP also created a company, Hydra-Cushion Inc., in Chicago to profit from the innovation. By the beginning of 1963, over 6000 railcars on 20 railroads had been modified with Hydra-Cushion and at least five other companies had sprung up with competing designs.[D] According to *Railway Age*, by 1967 over 125,000 railcars were equipped with underframe cushioning.[E]

In 1964 William MacCurdy received the Franklin Institute's annual George R. Henderson Medal. This gold medal was for achievements "in the field of railway impact control and associated car design, with resulting benefits in reducing lading and rolling stock damage." SP's William E. Thomford also received the honor, reflecting on the SRI tendency to work with, not just for, a client.[F] A final tribute from *Railway Age* in 1967 said this innovation made possible rail transport quality control programs that would have been previously "unthinkable." It concludes: "The 10th anniversary of the cushion-underframe…has to be one of the most significant anniversaries in the annals of the industry." [G]

The industry-wide benefits of Hydra-Cushion in reducing cargo damage, extending the life of the railroad car itself, and reducing maintenance costs were enormous. Considering that the Southern Pacific projects on which SRI first designed and tested Hydra-Cushion came to less than $20,000, this was a profitable investment indeed.[2]

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[1] According to SRI's Bill McGuigan, the prototype Hydra-Cushion cars worked so much better than the existing stock that the test cars sent out for operational tests would never come back! He also recalled, during a discussion on June 7, 2000, that he also knew they were working well when he received an irate phone call from a manufacturer of existing shock-absorbing couplers. The caller wondered what SRI was doing in this business and McGuigan kindly told him that his company could have retained SRI if they had been on the ball.

[2] Project 1226 was for $7,000 dated September 15, 1954 and Project 1648 was for $12,473 dated February 10, 1956; both for the Southern Pacific Railroad. Other projects followed in 1960 and 1965 for continuing testing and improvements to the concept.

SRI did a lot of other work for the railroad industry, much of which was built on its relationship with SP. We will mention just a few others here, starting with the design of a more efficient train operation system that better classified, located, and used empty rail cars.

Managing the Flow of Railcars

Imagine that you own 10,000 boxcars that are distributed not only across the areas where your railroad's primary tracks are located, but on those of other rail carriers as well. Several operating and efficiency factors immediately emerge. First, you need to have your own empty railcars available when they are needed at the site where your shipping opportunities exist. Second, by arrangement, at least back in 1955, your company must pay $2.75 per day for each railcar owned by another company that sits on your own tracks. Reciprocally, every empty car of yours sitting idle on your tracks is a lost opportunity of $2.75 per car per day if it could be loaned to other carriers. These demands on railroad operations sent the Southern Pacific Railroad to SRI for help in 1954. How could SP govern the movement of its 10,000 railcars to best advantage?[H]

SRI immediately saw the complexity in managing such a system. The network on which the cars (yours and other carriers') can move is complex in itself, and it is complicated further by the need to allow for the effects of weather on track availability and the time variability of demand. For example, unusual weather conditions such as higher or lower than expected temperatures can move crop harvest forward or delay it. Such complexities and many more led SRI to a statistical, operations research model for the rail system.

For over three years, SRI mathematicians and engineers observed the sources and time movements of the various grades of railcars (important as to what they could carry) and modeled them. The model was used to characterize a given week's operation of car distribution for Southern Pacific's system. Most important, the system could forecast the holdings and movements required to meet the coming week's empty railcar needs. This prediction ultimately defined not only what empty cars should be moved each week between the SP's operating divisions to provide the most efficient flow of goods, but also how many empty cars should be ordered from connecting railroads.

The SRI model was implemented on an IBM punched card and data processing system and tested and put into use on Southern Pacific's Pacific Coast Line that extended 8,000 miles from Portland, OR to El Paso, TX.

Such models are of little use, of course, unless you first have some idea where the railcars are located in both time and space. Being able to form and reform trains also requires knowledge of where trains and their constituent cars are in the collective rail system. In the early 1950s, this information was typically gathered manually, either by men walking the tracks as trains paused at certain stations or by monitoring closed-circuit television cameras at points where trains were moving slowly. The manually gathered information was then telegraphed or phoned ahead to the next branching points. It was a slow and tedious process.

Around 1957-1958, the New York Central Railroad raised the problem with the A.B. Dick Company, a Chicago printing company that had an ongoing relationship with SRI. Was there a more efficient way the information could be collected and forwarded along the rail system so as to facilitate the rebuilding of trains or the management of empty cars? Since the cars were then identifiable only by the alphanumeric indicators on them, SRI quickly devised a high-speed imaging system that would capture the information as the train sped by. In this case, the image was of the entire train. The television camera imaged only a very thin vertical slice of the train at any instant, letting the movement of the train define the horizontal aspect of the image. The output of the camera was microwaved or cabled ahead where a version of the SRI Videograph would print out the image of the entire train (see Chapter 7). The printer was extremely fast, moving a two-inch-wide paper at something like 36 inches per second. Although the system went into use, it still left the reading of car numbers from the image to be done manually.[3] Later, car identification would be done using barcodes.

[3] Later the Denver & Rio Grande Western Railroad contracted with A.B. Dick for an SRI Videograph system to pass way-bills and other printed material much more quickly—in effect a very high speed facsimile system.

Other projects for Southern Pacific continued into the 1960s. For example, SRI looked into the old technology used in grade crossing warning systems. SRI, working with SP engineer A.C. Krout, replaced the long-used block system, one whose trigger activated when a train crossed into a certain grade-crossing zone and which required rails to be electrically isolated in that zone. SRI designed a better and more easily implemented system that was based on both the position and the velocity of the train and required no isolated sections of track. The objective was a system that could be fitted to any crossing and would provide a safe and minimum-delay experience for the automotive public.

The technique, designed by SRI engineer Carroll Steele, used the two rails as a transmission line, the reactance of which was indicative of the train's distance. SP conducted long-term tests on the SRI innovation. SRI's testing of the new crossing alert system began in 1961 and fail-safe features that checked the system every five seconds were integrated into a design that was in production by early 1963.[I] That production occurred at the Pomona Division of Marquardt Corporation who later sold it to Safetran, where it is still manufactured today.[J]

In another project for Southern Pacific, SRI built a journal infrared system that would detect the presence of high-friction wheel bearings or "hotboxes" as trains rolled by. SRI then designed methods for controlling the speed of the car at train-building hump yards to minimize coupling speed and reduce noise. Finally, SRI also determined why fires sometimes occurred in the shipping of cotton fibers and the role of railroads in restoring the civil infrastructure in the advent of a nuclear attack.

A Very Early Airline Reservation System

The year was 1956 and United Air Lines was getting behind in its ability to determine and schedule its available passenger space. United had conducted an internal study to look at the long range needs for controlling space utilization and determined that engineering consultants should be hired to design and implement a "space control system." In October of that year, United asked SRI for that help and the following month signed a five-month, $85,000 contract to design a solution to this problem.[K]

At this time in the development of computers, stored-program general-purpose computers had only modest capability but were evolving rapidly. Reliability was an important issue, particularly to this client. So the question arose as to how far this system should go toward automating passenger reservations. To be conservative, United decided to go part way; that is, to build a system that kept track of the available space, in this case seating, and make that information available to ticket agents. The ticket agents would then perform by hand the match between the available seat and the passenger. They would then pass back to the system the information needed to update the seat inventory.

SRI completed its work on time and issued a 182-page system design and information for United to use in making the appropriate hardware selection. The system was a hybrid of centralized and decentralized design, depending on the function in play. To have an unambiguous resource on the booked (ticketed) and available seats, there was one, centralized accounting of that data. Because of the repeated queries about the availability of seating without a booking, those data were decentralized to United's six metropolitan sites. Figure 6-4 shows a composite map of the system taken from the SRI design.

To meet the use specifications United had provided, simulations had to be done, including such factors as inquiry waiting time statistics. These simulations included modeling the frequency and types of various expected queries. The limit on a seat query was 3 seconds and for a booking was 15 seconds. These constraints boiled down to the design of both machine capacity and line traffic volumes. The specifications also called for 400 flights per day, 1000 ticketing agents, and 85,000 bookings or cancellations per day.

SRI also identified two implementers, Remington-RAND (UNIVAC) and Teleregister Corporation, and asked them to provide quotes

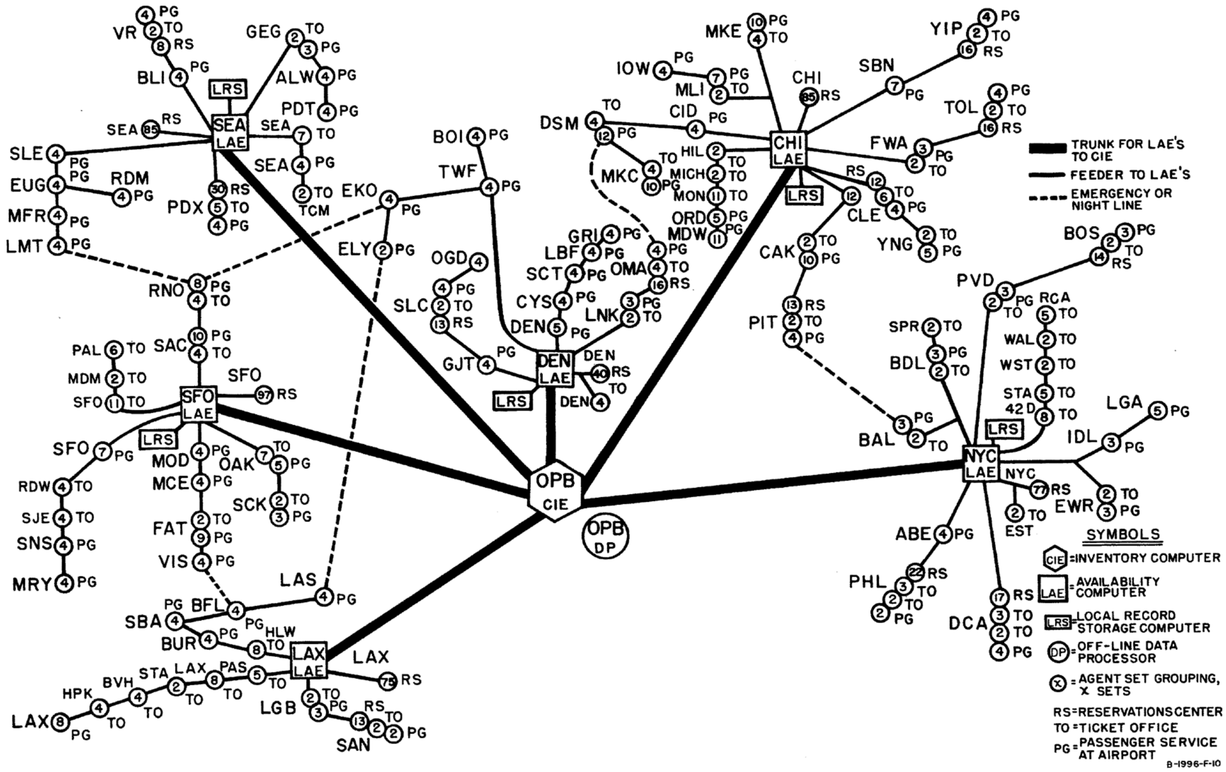

Figure 6-4. Equipment layout and map of proposed generic air reservations system for 1965 (from SRI's final report to United).

on the generic system design, costs, proof of capability, time to implement, and reliability. From these quotes, United chose Teleregister of Stamford, CT, as the implementer. Teleregister had made its name in the brokerage industry and for perhaps a decade Teleregister had been placing increasingly capable reservation systems in the sales offices of various airlines. Teleregister's reservation system, called Reservisor, consisted of relays, rotating magnetic drums, and some electronics. Teleregister was also one of the first companies to integrate completely the functionality of communications and computing. All this experience gave them a good understanding of the functionality needed by United.

This new system was not only a new, more intensely computer-based technology, it was also a much larger, distributed system, able to give 24-hour reliability. To gain that reliability, two computer systems had to be run in tandem so that when one failed the other would immediately pick up the task. Internally, Teleregister called it an Electronic Reservation System. Because of SRI's familiarity with the design, SRI was asked to help United monitor the fabrication and define the functional tests of individual components and then the complete system. The design goals for the system were to meet or exceed the predicted 1965 traffic load, but SRI had laid out interim years and the capability the system needed to have. So, in a follow-on small contract, SRI also designed tests for traffic handling, response time, fault detection and attribution, and the overall reliability of the system as a space management tool.

By May 1961, Teleregister had installed the United system. United called it Instamatic. As the potential of the new system became apparent, United asked Teleregister to propose an integrated system that would go far beyond passenger reservations to other airline operations. These included freight, flight scheduling, pay, maintenance, profit and loss, and even load and fuel balance on each flight.[L] Teleregister submitted the proposal, and it was so well done that United used it as a basis for a competitive bid, which ironically was won in December of 1965 by Remington-RAND UNIVAC. This, I believe, ultimately evolved in part to United's Apollo reservation system, which is still an important player in the world of airline reservations.

So, what was SRI's net position in the rapidly evolving computerization of the airline industry? Unfortunately, not much. IBM was at the same time working with American Air Lines to build SABRE, which was in partial operation in 1960 after an investment of 400 labor-years and $40 million. Its first installations were of about the same size as the SRI design, but the system continued to grow. Its final cutover to operations was made in 1964. The SRI-defined system, then, had but a few years at United where it was a prominent part of the first airline reservation systems.

The Containerization of Ocean Shipping

One of the most obvious revolutions in the business of ocean-going cargo transport is the ubiquitous cargo container. Many ships are now made strictly as container carriers, and as they leave port, they seem to brim and even overflow with containers "pasted" to every flat spot. The larger vessels can now hold the equivalent of 6,000–10,000 containers, 8 x 8 x 20 ft in size. Not only does containerization enormously simplify and accelerate the loading and unloading of ships, but that ease of movement continues as other carrier forms, such as trucks and rail, cradle the same container aboard with hardly a missed beat. One of the pivotal aspects of such a flow of cargo is, of course, the need for standardization, both for dense nesting and for ease of transfer between various forms of so-called intermodal transport.

During the 1960s, SRI had a hand in the growth of this type of cargo transport. Much of the ultimate purpose of this work was to prepare the rationale for both individual maritime carriers and shipping ports in their transition to containerization. These studies required examining the adaptability of various kinds of cargo to a range of container sizes as well as estimating the cargo traffic that would justify the huge capital cost of conversion. With logistical specialists, naval architects, economists, and mathematicians on SRI's staff, virtually all aspects of the new containerization concept could be analyzed.[4]

[4] Some of the prominent SRI players in this work were Ben Andrews, Fred Witzel, Vance Miller, Robert Brown, Neal Houston, Beverly Taylor, Robert Hubenette, Phil Adams, and Ogden Hamilton.

SRI performed modular cargo handling and traffic studies for some of the world's largest cargo fleets, including the following carriers, ports, and passageways:

- Carriers
  - Johnson Line (Sweden)
  - Maersk Line (Denmark) (now includes Sealand)
  - China Overseas Shipping (Taiwan)
  - American President Lines (USA)
  - Columbus Line (Germany)
- Ports and Passageways
  - Tampa Bay, Tacoma, Portland, and the States of Alaska and California (USA)
  - Bahia Blanca, Rio Gallegos, and Santa Cruz (Argentina)
  - St. Lawrence Seaway Development Authority (Canada)
  - The Canadian Atlantic Development Board (Canada)
  - The Panama Canal Co. (Panama)
  - Al Aqabah (Jordan).

Most of this work was done in the 1960s when all carriers were struggling with the proper container configuration for their existing and proposed fleets, the routes over which containerization made sense, and the timing for transition. This work consisted of exploring appropriate container handling systems as well as elaborate simulations on where, when, and how transitions were best made.

One client on the list, The Canadian Atlantic Development Board, was a government board for whom SRI explored an interesting problem: the very seasonal uses of the Canadian ports of Halifax and St. Johns in spite of their being year-round ports.[M] Because of the summer opening of the St. Lawrence passage, ocean-going freight would bypass Halifax for the inland port of Montreal. Then, with the introduction of icebreakers, the seaway was kept open much of the winter. So, in the early 1960s even the cyclical use of the two coastal ports was dying. In 1964 the Canadian Atlantic Development Board asked SRI to look specifically at the containerization in the North Atlantic via Halifax and St. Johns.

Figure 6-5. Large container ship at Halifax (taken from the online version of the *Port of Halifax Magazine,* July/August, 1999)

In a nutshell, the answer was that Halifax could be a year-round port for the large container ships whose great circle route to New York passed close by. So investments were made and the first container ship docked in Halifax in the summer of 1969.[N] By the turn of the century, the port was serving more than 20 carriers and handling almost a half million containers per year. Both truck and rail transport then distributed them across Eastern Canada and the United States.

Several studies for the Panama Canal Co. were surveys of the future traffic it might expect, a basis for revenue prediction, and the configuration forthcoming ships might take as the containerization process matured.

SRI's early advocacy of containerization was indicated in a speech SRI marine engineer/naval architect Benjamin Andrews gave in San Francisco in 1967. There he outlined the trend toward specialty ships and away from the general-purpose cargo vessels of the past. He argued for the broad benefits of containerization including greater speed, lower shipping and insurance costs, and one of the biggest virtues, the ease of transshipment.[O] The revolution is still in full swing with about 25 million containers transiting U.S. ports each year.

The Maglev Project

Early in the 1900s, magnetic levitation (maglev) had been proposed as a way to decrease the friction of a ground vehicle. However, the various approaches proposed were so inefficient they were judged economically infeasible. In 1963, however, the field was reopened to more investigation with the notion of using low-loss, cryogenically cooled, superconducting magnets. The late 1960s saw ongoing research and development work in Germany, England, Canada, and Japan and in special, non-transportation needs in our own Department of Defense. This DoD application explored using maglev to build extremely high velocity sleds, and SRI was involved.[P] So, in 1970 when the U.S. Department of Transportation decided to let a few research studies to explore the practicality of the concept for a rail system, SRI was ready and won one of those contracts in February 1971.[Q]

The purpose of the SRI study was to examine the technical feasibility of various methods of levitating high-speed ground transportation vehicles. SRI examined the use of permanent magnets, conventional electromagnets, and superconducting magnets. In work that continued for over three years, SRI physicists defined the theory, analytical models, and experimental outcome of maglev. Experiments were conducted on a 500-foot aluminum test track built on the SRI back lot. They used a 1 by 4 m sled to test levitation methods and to measure the control dynamics required to both lift and guide the sled in its track.

During the first year, the sled was not totally levitated but was used to measure a variety of levitating approaches. By 1972, the 300-kG sled was completely levitated and guided by magnetic forces. Levitation was achieved by four 28 by 32-cm magnets cooled to minus 450°F. Figure 6-6 shows the sled and track. Clearances in the track were purposefully set so that the sled could have 15 degrees of roll, pitch, and yaw without restriction. Thus, the vertical and lateral positionings of the sled were controlled by magnetic guidance and damping systems. Its forward motion, however, was defined by an endless cable and winch arrangement. Thus, the electromagnetic or other forward propulsion aspects of maglev were not explored at SRI.

The results of the work showed that all three types of magnets were capable of meeting the project design goal of suspending a 100,000-lb vehicle. However, when a host of considerations were factored in, such as estimated costs, ride comfort, and operating characteristics, the superconducting, repelling force, maglev, was the most favorable. Superconducting materials, in this case obtained by cryogenic cooling, approach zero resistance and therefore the induced current, in

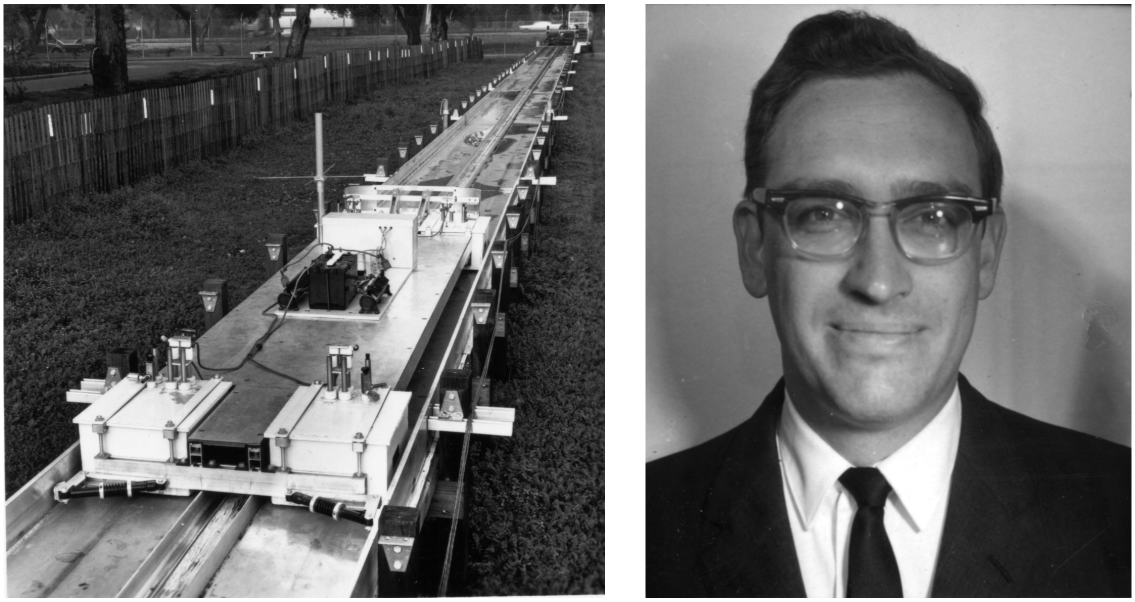

Figure 6-6. The SRI maglev sled and test track located at SRI (Nov 1972) and its principal designer, Howard Coffey.

this case about 100 amperes, will persist as long as the temperature is maintained. These magnets can also use simpler continuous conducting-sheet guideways and are amenable to electromagnetic damping systems needed for ride comfort and guidance control. The superconducting magnets designed at SRI would allow a vehicle to clear the guideway by 8 inches at a speed of 300 mph. SRI's maglev work continued for about 3 years until the DoT terminated its interest in the area.[R,S]

Although the United States lost interest in this subject for a time, work continued in Europe and Japan through the 1980s and to the present. China recently fielded the world's fastest maglev train, having a 268-mph peak velocity and linking downtown Shanghai to its airport. The ride is smooth and each train can carry nearly 600 passengers.[T]

Endnotes

[A] This and other information for this story came from: Era of car cushioning began 10 years ago, *Railway Age*, February 27, pp. 34–35, 1967.

[B] William K. MacCurdy, *Comparative Impact Tests of the Hydracushion Underframe*, Final Report, SRI Project 1648, July 1956. Also SRI *Research for Industry*, 8(2), 10–11, January 1956.

[C] Softer Rides for Rail Freight, *SRI Journal*, 2 (2), 44-45, 1958.

[D] SRI's *Research for Industry*, 15(1), 10, January–February 1963.

[E] *Railway Age*, op. cit.

[F] A Research Accomplishment Acknowledged, *SRI Journal*, 2, 12 1964.

[G] *Railway Age*, op. cit.

[H] SRI's *Research for Industry*, 9(4), 1-3, May 1957.

[I] SRI's *Research for Industry*, 15(1), 14, January–February 1963.

[J] Email from Carroll Steele dated June 14, 2004.

[K] R. C. Amara, Bonnar Cox, George A. Barnard III, T. H. Meisling, and Oliver Whitby, *A Unified Electronic System for Passenger Space Control*, Final Report on SRI Project 1996, Contract No. 9001 for United Air Lines, Inc., May 1957.

[L] Dr. William Mitchell, Professor of Information Science, University of Arkansas, *The Genesis of NASA RECON*. Taken from www.ualr.edu/~wmmitchell/NASARECON.htm.

[M] SRI Project 5472 for $22,200 conducted from December 28, 1964, to August 14, 1965.

[N] The Magic Box, *Port of Halifax Magazine*, July/August 1999. (Mentions their contracting for two studies to address the plight of the port at Halifax.)

[O] Benjamin V. Andrews, The Changing Future of Marine Transportation, Speech to the San Francisco Traffic Club, March 15, 1967.

[P] T. W. Barbee, G. N. Bycroft, E. G. Chilton, F. M. Chilton, and H. T. Coffey, *The Hypervelocity Rocket Sled—A Design Analysis*, SRI Project PMU-7014, July 1968.

[Q] Federal Railroad Administration, Office of High Speed Ground Transportation, Contract DOT-FR-10001, $121,337, February 8, 1971, to January 7, 1972.

[R] *The Feasibility of Magnetically Levitating High Speed Ground Vehicles*, Final Report Task I, SRI Project 1080, February 1972, NTIS Report No. PB-210505.

[S] H. T. Coffey, Magnetic Suspensions for High Speed Vehicles, in *Advances in Cryogenic Engineering*, Vol. 19, p. 137, 1974, Plenum Press.

[T] Faster Than a Speeding Bullet Train, *IEEE Spectrum*, 30-34, August 2003.