Working Paper 2A.2:
Initial Definition and Description of Bay Bridge Rail Options

Bay Bridge Rail Alternatives Study
Metropolitan Transportation Commission

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I. Executive Summary

The study of potential rail applications on the San Francisco - Oakland Bay Bridge is limited to an evaluation of the feasibility and implications of the installation of any of several possible passenger rail modes on the "planned retrofit design" of the existing West Span (between Yerba Buena Island and San Francisco), and on the "currently designed new East Span" (between the Island and Oakland).

This Working Paper presents an initial "sketch plans" of rail options, focusing for the most part on the issues associated with a rail installation on the Bridge itself, and on some of the significant implications of those issues for the Transbay Terminal, since that facility is also under specific study. This Working Paper does not go into detail about service plans, routings or networks on either side of the Bay, other than to provide a level of descriptive detail useful to a basic understanding of each alternative rail concept.

At a later phase of this study, when some of the structural evaluations have been undertaken, rail concept refinement will be conducted, and a more detailed definition of the potential rail systems will be prepared. These sketch plans are intended to permit structural and traffic studies to begin by providing basic concepts and data for the rail alternatives.

II. Previous Bay Bridge Passenger Rail Services

Passenger rail service was provided over the Bay Bridge from 1939 until 1958. A description and history of this service was provided in Transbay Terminal Improvement Plan Working Paper 2.1: Terminal History. Some key points of that history are directly pertinent to this study, and may be summarized as follows:

- The "Bridge Railway," as it was known, is remembered today primarily for its use by the "Key System," a privately-owned predecessor of AC Transit, which operated a regional transbay rail service between San Francisco and East Bay cities. The Bridge Railway and its associated Terminal in San Francisco were state-owned facilities, and the private operating companies making track connections with the Bridge Railway in Oakland paid a fee to use it.

- When it opened in January 1939, three companies operated on the Bridge Railway: the Key System, the Interurban Electric Railway Company (or "IER," successor to Southern Pacific), and the Sacramento Northern Railway (SN). Key and IER operated most of the trains, providing regional transbay service between San Francisco and the cities of the Central East Bay as AC transit buses and BART trains do today. The Sacramento Northern operated a small number of trains, some commuter trains to Concord and Pittsburgh, and some through inter-regional trains to Sacramento and Chico. Modern successors to the SN service are the BART Concord-Pittsburgh line, which utilizes some of the SN right-of-way between Walnut Creek and North Concord, and the Capitol Corridor trains operated by Amtrak California. All service over the Bay Bridge was electrified, with two different operating voltages provided on the Bridge. Weight, length and capacity for representative examples of the rolling stock operated by these companies are included in the table in Appendix B.

- The Bridge Railway was designed to accommodate up to 40 million passengers per year, and initially a high volume of service was provided. There were 500 trains scheduled over the Bridge Railway to and from the six-track Transbay Terminal each day in February 1939. Between 4:30 and 5:30 PM, 37 trains were scheduled to depart the Terminal for the East Bay, an average headway of about 97 seconds. This is a very high capacity; if all trains scheduled had been ten-car trains with more than 100 passengers per car, the Bridge Railway would have had a scheduled capacity in the range of 40,000 passengers per peak hour per direction. Speeds were low on the Bridge, a maximum of 35 mph permitted by the signal system. A station at Yerba Buena Island was added during the war to handle heavy passenger traffic to and from Treasure Island.

- The original configuration of the Bay Bridge provided for six automobile lanes on the upper deck (three in each direction), three truck and bus lanes on the northern part of the lower deck (one in each direction plus a passing lane), and two Bridge Railway tracks on the southern part of the lower deck. After the abandonment of the Bridge Railway in 1958, and its subsequent removal, the Bridge was reconfigured to one-way operation on each deck, and a highway traffic approach onto the lower deck from the Harrison/Bryant freeway structure was constructed. The upper deck of the Yerba Buena Island Tunnel was also lowered at that time in order to provide adequate height clearance under the arched tunnel ceiling for trucks in the outer lanes of the upper deck.

III. Technology Options for Bay Bridge Passenger Rail Service

A. Regulatory Impact

In the sixty years since the design of the original Bridge Railway, new operating practices and a new regulatory framework have developed, both of which have a direct bearing on the options which can realistically be considered for passenger rail service on the Bay Bridge. Specifically, it is no longer legal to co mingle the operation of light weight trains designed for on-street light rail operation or rapid transit in the East Bay with inter-regional or intercity trains intended for commuter rail systems or mainline service. This is an important consideration, because in the course of the public discussion of a new Bridge Railway, statements have been made about running both a new light rail service (a new "Key System," for example), and Capitol Corridor or high speed trains over the Bridge into San Francisco. This is no longer possible on the same set of tracks because of safety regulations enforced by the Federal Railroad Administration (FRA). While the regulatory system is still evolving, the trend is definitely toward even stricter separation of transit trains and FRA-compliant mainline equipment.

The implications of the body of passenger rail regulations on transbay rail options was reviewed at some length in Transbay Terminal Improvement Plan Working Paper 2.3: Rail Service Issues and Impacts, and there is no need to repeat that entire discussion here. (Excerpts are presented in Appendix A). For an initial description of sketch alternatives, it is sufficient to conclude that there are two fundamental groupings of passenger rail alternatives for a new Bridge Railway: **transit-based alternatives** and **railroad-based alternatives**.

While many potential transit service options exist for the East Bay, as far as the Bridge is concerned, two transit-based options will be considered: light rail, and a BART relief line. Within the group of railroad-based alternatives, a commuter rail service providing regional connections between San Francisco and the Greater East Bay, or a passenger rail link to Sacramento and Stockton might be accommodated. Amtrak's new high speed trainsets designed for the Northeast Corridor are another possibility, though they would probably run at conventional speeds over the Bridge itself. Conceptually, both high speed and conventional railroad equipment could be accommodated on the same Bridge trackage, although weights and minimum acceptable radii of curvature need to be evaluated.

B. Available and Appropriate Technology

For the illustrative purposes associated with these first sketch descriptions of Bridge rail passenger options, only rolling stock actually available for use in the United States will be used. The objective is to assess the ability of the Bay Bridge to accept the operation of rail options that are, to the degree possible, known quantities, free of speculation about weight or performance. Thus the equipment types listed below have been chosen, in part, because of the amount of available data about each of them.

For light rail, this working paper will assume the Portland Type 2 low-floor car. This is a large light rail car intended for regional service on routes stretching up to 18 miles from the urban core, as distinguished from a car intended for a purely local urban service. It is also the only low-floor car currently in operation in North America, and a great deal is known about its capabilities. For BART, the dimensions and characteristics of a C-Car will be used.

For the railroad based options, two different but compatible types of rolling stock will be used to test the Bridge's capabilities: an electrified multiple unit ("EMU") commuter car, and the Amtrak "Acela" high speed trainsets. Several different EMU options exist, with varying characteristics. For illustrative purposes a "SEPTA" (Philadelphia based Southeastern Pennsylvania Transportation Authority) car with an extensive history, including applications in center city tunnels and on grades almost as significant as those potentially

under consideration here, will be used for illustrative purposes.

An EMU application rather than diesel locomotive-hauled trains of unpowered cars is proposed for several reasons:

- EMU trainsets have all axles powered and can thus provide a high level of tractive effort over a range of gradients similar to those likely to be encountered in the Bridge crossing. Examples would include the incline from the Toll Plaza level to the Bridge elevation; "flying junctions" with the Union Pacific in Oakland and/or Emeryville; the climb from a dead stop at the Transbay Terminal, around minimum radius curves and up to Bridge level; and the grade in a potential Rincon Hill Tunnel linking the Caltrain service with the Transbay Terminal rail deck, and therefore also with the Bridge trackage.

- Despite their poorer performance, diesel locomotives are heavier, and would impose greater axle loadings on the Bridge. A modern commuter rail locomotive such as an F59PH of 3,000 horsepower, weighs 135 tons, or 67,500 pounds per axle, more than twice the concentrated loading of an EMU (see Appendix B for more comparisons).

- High speed trainsets would require electrification in any event, and since the intent would be to accommodate them as well as conventional commuter or inter-regional trains on the same tracks, an electrified commuter service would seem appropriate.

- Alternative Caltrain extensions to the Transbay Terminal are based on the assumption of electrification, and San Francisco City policy calls for an electrified extension of Caltrain service to the Terminal. Any through routing of Peninsula trains via the Terminal to the Bridge and the East Bay would almost certainly involve electrified equipment.

For these reasons, it is proposed that the commuter rail and associated inter-regional passenger rail options used for evaluation purposes in this study be based on an EMU concept.

The use of the Acela trainset for a high-speed option assessment may be controversial. European and Japanese high speed experience is now quite extensive, and were the American regulatory environment not so restrictive, a more aggressive choice than the 150mph Acela might be recommended. Certainly, the California High Speed Rail Authority has not yet made any decisions about the specific type of technology to be proposed as part of the statewide system. However, it is important to take several matters into consideration:

- The Acela trainset is the only FRA-compliant high speed set in existence.

- The FRA has indicated that it intends to assert regulatory oversight over all high speed rail projects in the country, whether or not they are connected with the general railroad system; therefore, some level of FRA requirements will have to be met one way or another. Although a different design may eventually be approved by the FRA for applications that are fully grade separated and not connected with the general railroad system, no design has yet been given such approval.

- The Acela trainset has known weight, length, power and capacity data, and although it is still being tested, much is known about its operational characteristics in an American operating environment.

- Weight and performance impacts associated with bringing any Japanese or European

technology into compliance with FRA regulations for an operating environment composed of both high speed and conventional trains would involve speculation and guesswork.

- If a demonstration of feasibility is based on the Acela trainset, then it may be presumed that any lighter weight equipment that might ultimately be found acceptable for American operations could also be used on the Bay Bridge. On the other hand, a finding of feasibility based on a technology whose deployment on American rails is somewhat speculative could leave the matter of high speed trains on the Bay Bridge almost as unresolved as it is at present.

For these reasons, the high speed rolling stock option proposed for use in this study is the Amtrak Acela trainset. This does not necessarily mean that a different high speed rail technology selected by the California High Speed Rail Authority could not operate on the Bridge, or even that a lighter weight system might not eventually be granted a waiver by the FRA for operation on the Bridge co-mingled with other passenger services at conventional speeds. It only means that this evaluation of high speed equipment on the Bridge is being conducted using a more stringent test basis, i.e. a heavier trainset.

IV. Bay Bridge Passenger Rail Alternatives

Alternative A: Bay Bridge Light Rail

Insofar as Bay Bridge loadings and service levels are concerned, this concept is the same as that in the 12 April technical memorandum describing "Draft LRT/Bus Assumptions for Terminal Programming." Subsequent to that memorandum, comments were received from AC Transit staff on alternative routings of potential light rail lines in the East Bay. Those are not reflected in this Working Paper, as the details of the East Bay network concept are not an issue at this point, but they will be addressed in a later task of this study.

The light rail vehicle being assumed for the purposes of this study is the Portland Type 2 low-floor car. The 72-seat car is 92 feet long, and weighs 109,000 lbs. empty. It is sometimes referred to as a "six-axle" car, but actually the car's low floor runs through the articulation section, so that the four center wheels are axle-less, and are mounted directly to the frame of the car.

For the purposes of this Working Paper, it is supposed that light rail trains might operate in three-car consists on a five minute headway. The overall concept is described in the 12 April memorandum, which, minus the Terminal sketches, is reproduced as Appendix E to this Working Paper.

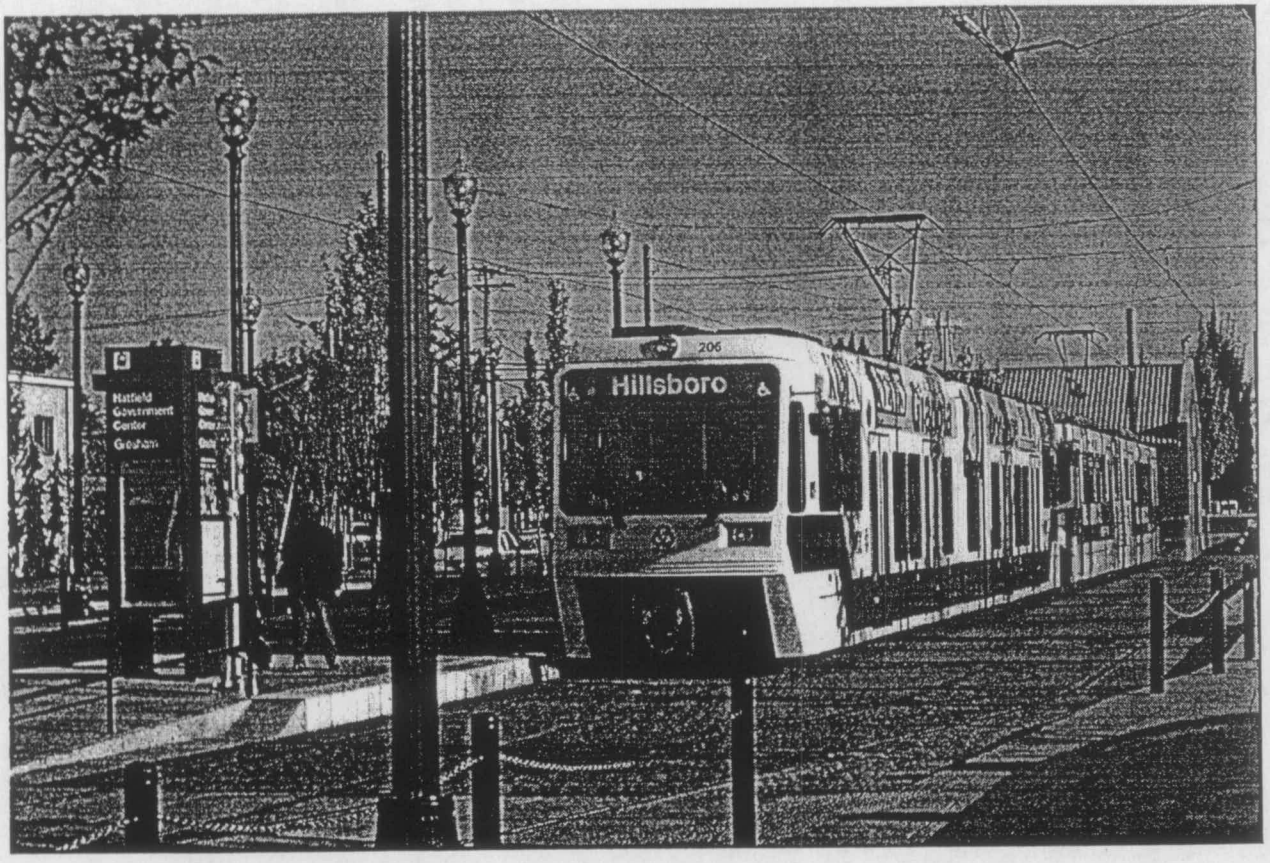


Figure 1. Portland Type 2 Low-Floor LRV

Alternative B: BART Relief Line

It is presumed a potential BART application on the Bridge would operate as a "relief" line providing additional capacity during BART's constrained peak period, though it would presumably provide all-day service. BART's main peak capacity constraint in providing Transbay service is the section between the west end of the Oakland Wye and Daly City; in this segment, while there are crossovers available to turn trains back, there is no third track available. An additional route across the Bay, connecting into the existing BART system south of MacArthur Station, or into the main point of constraint at the Oakland Wye, then running independently to and over the Bridge to the Transbay Terminal, could provide considerable additional capacity.

For evaluation purposes in this stage of the study, a BART C-Car will be used. These cars are undoubtedly familiar to all study participants. This is a four-axle, 70-foot car with 68 seats; it weighs 63,800 lbs. when empty.

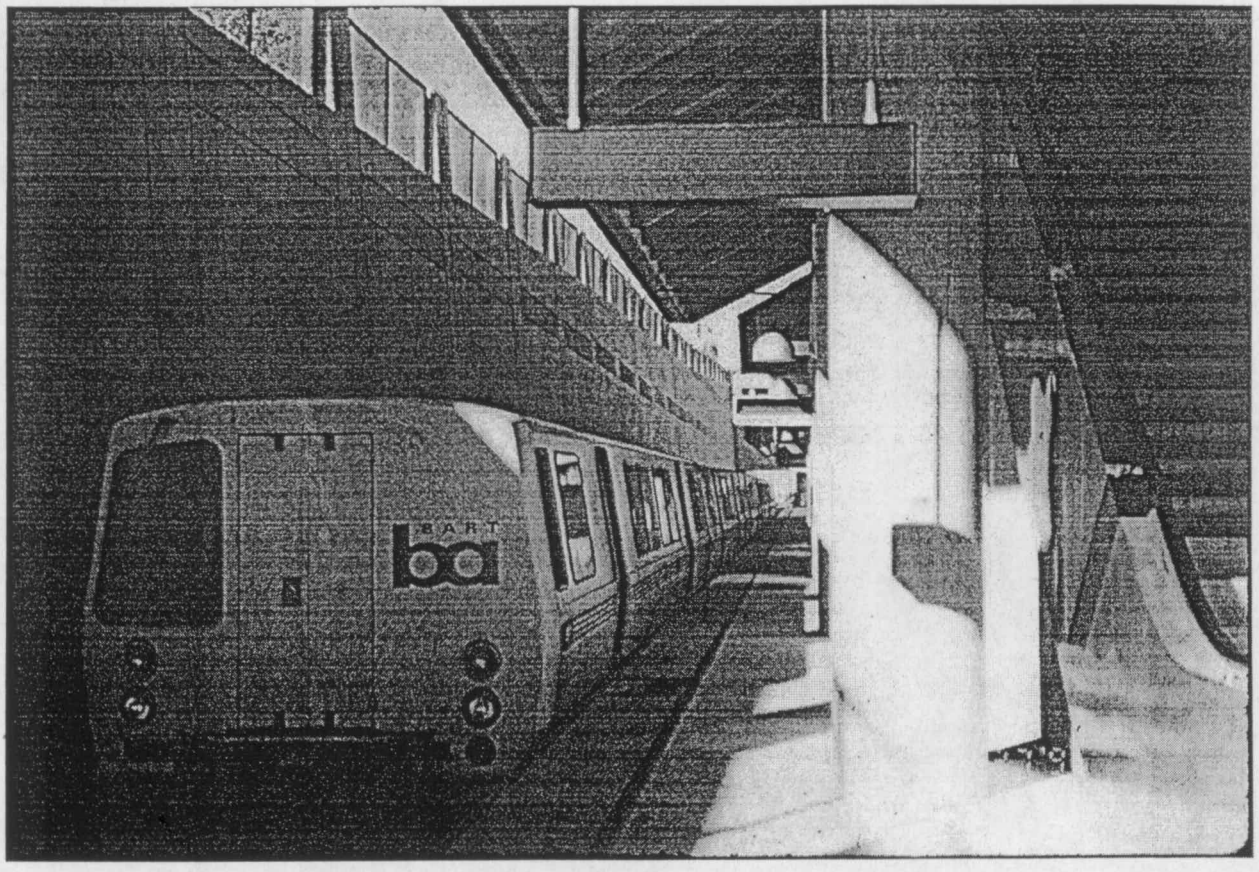


Figure 2. BART C Car

Alternative C: Commuter Rail, FRA Compliant

The commuter rail service option would, as noted above, be based on available EMU technology. Trains would operate in consists as long as 8 to 10 cars in length, depending upon platform lengths at the Transbay Terminal and at other stations. It is assumed that two-person crews would be used, with proof-of-payment fare collection employed. In the East Bay, track connections would be provided in West Oakland/Emeryville to the Union Pacific Railroad towards both Capitol Corridor destinations (Berkeley, Richmond, and other stops toward Sacramento), and toward Downtown Oakland and destinations south to San Jose, and south and east over Altamont Pass to the San Joaquin Valley.

For purposes of this study, the weight and other characteristics of the SEPTA suburban Philadelphia EMU fleet will be used. Electrification would be carried out using contemporary proven technology, presumably at 25kV AC. By combining a potential Rincon Hill Tunnel approach to the Transbay Terminal with Bridge Rail, both Bridge Rail and Caltrain services could conceptually use the upper level of the Terminal, and trains might potentially be through-routed from Capitol Corridor points to stations on the Caltrain line. While full exploitation of this concept would depend upon complete mainline electrification, an initial phase of service might be considered in which electrification was installed from Oakland/Emeryville to San Francisco International Airport, with EMU's continuing beyond the end of electrified segments in the consist of diesel locomotive-hauled trains.

Some of the performance characteristics of SEPTA "Silverliner" EMU's are described in Appendix C.

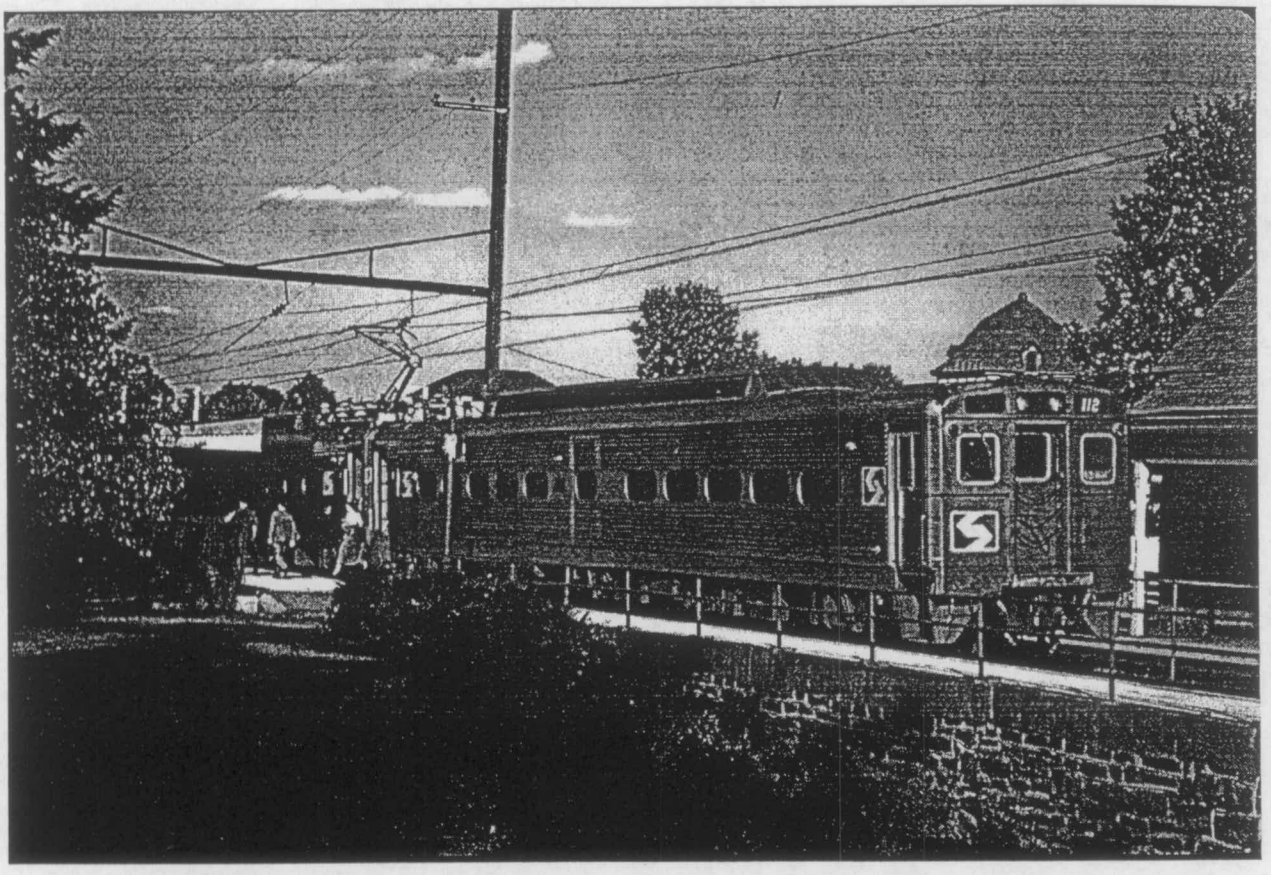


Figure 3. SEPTA Regional Rail EMU

Alternative D: High Speed Rail

The AMTRAK Acela high speed trainset will be used as the example of rolling stock for the evaluation of this alternative. It is assumed that the track and infrastructure used for the FRA compliant commuter rail service could also be used by the high speed trains. The Acela equipment is designed to run on the general Northeast Corridor system, including the Philadelphia-Harrisburg line. It is understood that these trainsets can run on curvature, albeit at low speeds, of 250 foot radius, which is approximately the curvature of the Transbay Terminal loop. It is therefore conceivable, provided that weight and other factors do not prevent

it, that it may be possible to route Acela equipment into the Terminal either from the Bridge, or from the Peninsula via a Rincon Hill Tunnel, or both. It could be a tight fit, however.

Each Acela trainset consists of a fixed arrangement - two "power cars" (locomotives), with six cars in between, including 5 coaches (one first class, four coach class) and a bistro car. The trains can operate on three different voltages, including the new 25kV AC electrification between New Haven and Boston. That is the voltage assumed here for study purposes. Estimated seating capacity of a trainset is 304, plus crew. Trainset length and weight statistics are provided in Appendix B.

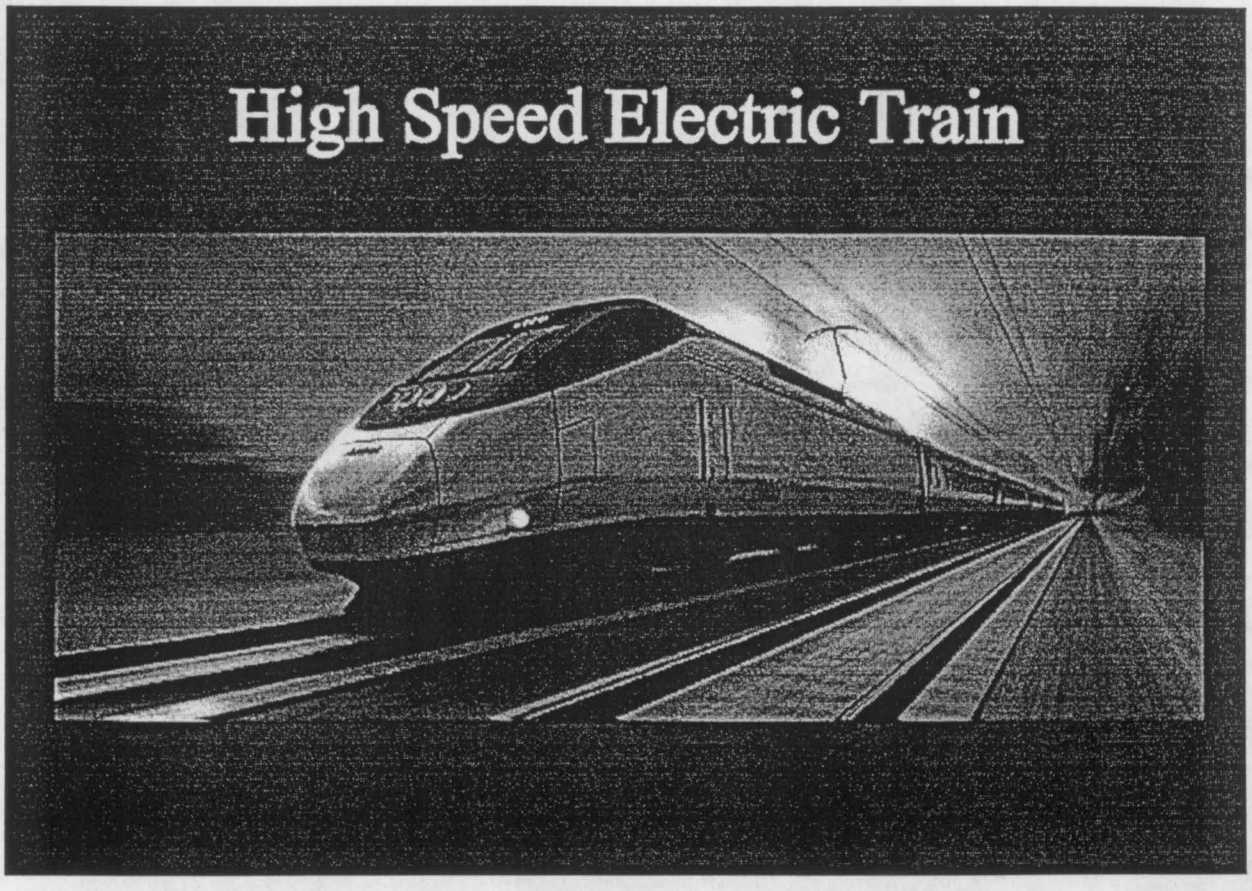


Figure 4. Amtrack "Acela" Trainset

V. Track Configuration and Stations

It is assumed initially that the Bridge Railway would consist of a fully double-tracked line, electrified at the appropriate voltage, and signalized to permit the fastest speeds allowed by the Bridge's structure and geometrics. No assumption is being made at this time about the location of the tracks on the Bridge.

In the event that engineering considerations make possible the accommodation of only a single track, an evaluation could be performed of capacity and operations characteristics of the alternative rail modes under single-track conditions. While far from ideal, it is possible that service at an acceptable minimum level could be provided with one single-track segment of minimal length.

Intermediate stations between Oakland and the Transbay Terminal may be considered at Yerba Buena Island and on Rincon Hill. The Bridge Railway added a Yerba Buena Island stop, with bus shuttle to Treasure Island, when military traffic grew during World War II. It would appear desirable to provide a similar station and appropriate connections to water level in order to meet the transportation needs generated by the re-use and development of Treasure Island. This could be a location with great potential for a high market share for public transportation.

In San Francisco, the transit approach ramps between the Terminal and the Bridge also cross over Harrison Street on an existing structure. When the Bridge was built, this was an industrial area with little transit demand, but today it is a booming center of dense development which does not have good transit service. .A station at Harrison Street could provide excellent access between the Rincon Hill area, the East Bay, and other points reached by a rail service depending upon the option in question.

VI. Some Implications for the Transbay Terminal

At a later point in this analysis, the implications for the Terminal of different passenger rail options will be developed. However, some assumptions have been made in the course of the Transbay Terminal Improvement Plan, and other preliminary thoughts can be offered here in connection with the Bridge Railway alternatives. All initially assume retention of a loop configuration for the Terminal because of the inherently high capacity of a loop arrangement (see comparisons of terminal capacities in Appendix D). Final determination of track layout and Terminal capacity will depend upon a more detailed level of design, and probably an operating simulation.

Alternative A: Bay Bridge Light Rail
This arrangement was discussed in the technical memorandum of April 12. A double-track alignment (one track for each direction of travel) would use the Terminal approach ramps. Right-of-way could, in part, be shared with buses, particularly inside the Terminal where one track would be located adjacent to a shared bus loading platform (reconfigured from sawtooth arrangement to a straight edge in the segments where the rail loading areas would be located). A second through track permitting trains to bypass the loading berths would be built, and sets of scissors crossovers would permit independent access and egress to and from two loading berths, each long enough for three cars. An initial look at this options suggests that this arrangement would only be required in one of the through bus lanes, and that the two LRT berths would replace ten bus bays.

Alternative B: BART Relief Line
BART and bus operations would require entirely separate rights-of-way, even inside the Terminal. It is assumed that BART would have a Terminal and approach track arrangement similar to the LRT alternative, with two tracks in the Terminal itself. The difference would be that BART requires high platforms and an exclusive right-of-way, so that bus operation would have to be eliminated from the lanes converted to BART use. A split platform arrangement could be made workable, with BART on one side and buses on the other, provided fare collection issues were worked out.

Demand forecasts may eventually be needed, and additional operations analysis conducted, to determine whether more than two tracks might be required in the Terminal for BART purposes.

Alternatives C and D: Commuter and High Speed Rail
Like the BART alternative, it is assumed that FRA-compliant rail operations will require exclusive rights-of-way on approach ramps and in the Terminal. Depending on the results of demand forecasts and operations analysis, the required number of Terminal tracks could be determined. However, it appears likely that if both a Caltrain extension and Bridge Railway trains were brought into the Terminal on the same (upper) level, then that entire level would probably be used for trains, with six tracks. Depending on traffic, perhaps three tracks could be used for Peninsula trains and three for Bridge trains. A separate level would be required for buses.

A joint use of the Terminal for both Peninsula and Bridge trains might require a widening of the segment of the throat of the Terminal to four tracks, from the three-track width as built. Two of the tracks would be for Bridge service, and two for Caltrain. One configuration would use the inner two tracks for Peninsula trains; these tracks would descend to enter a Rincon Hill Tunnel and clear the north line of Folsom Street, while the outer two tracks would climb on the existing gradient, over Folsom street and up to the Bridge.

Prominent among the many critical issues here would be the loop structure radii, and the grades between the Terminal and the Bridge and between the Terminal and the Rincon Hill Tunnel, in comparison with the capabilities of EMU equipment and the Acela trainsets.

Appendix A: Excerpts from Transbay Terminal Improvement Plan Working Paper 2.3: Rail Service Issues and Impacts.

Section III. Safety, Regulatory Authority, and "FRA Compatibility"

A. The Regulatory Framework

In recent years, relaxation or elimination of government regulation has been the norm in transportation as it has been in other formerly regulated fields. In the railroad industry this has also been generally true insofar as it pertains to commercial regulation, but in matters of safety and operations, the regulatory structure remains largely unchanged. Furthermore, rail transit, whether light rail or rapid transit, is essentially a public enterprise, and in recent decades has always come with strings attached connecting it to all levels of government - a situation which remains intact.

In the United States, responsibility for railroad safety regulation, both freight and passenger, rests primarily with the Federal Railroad Administration, the "FRA," which is part of the U.S. Department of Transportation. The FRA's jurisdiction extends to all trackage which is part of the nation's "general railroad system," and to all trains operated on that trackage, including long and short-haul passenger services, commuter trains, and high-speed trains, as well as freight trains. The body of regulations goes back many decades, and has been added to and modified many times to incorporate changes in response to technological change in the industry. The regulations are essentially embodied in federal law as CFR49, Parts 200 through 266; additional regulations not presently enacted, but published for industry discussion and comment under notices of proposed rulemaking, are pending, and likely to be enacted soon.

In general, the FRA's jurisdiction does not extend to rail transit services that are not part of the "general railroad system." Although there was historically some involvement of the FRA in some non-railroad rail transit matters, this was basically changed with the enaction of ISTEA, the federal transportation act, in 1991. ISTEA added Section 28 to the Federal Transit Act, establishing the "Rail Fixed Guideway Oversight Program." This Program requires each state having a rail transit system ("fixed guideway") to designate a state agency to be responsible for safety oversight of rail transit systems, and establishes a minimum set of requirements for the state to use in its oversight program. In California, the California Public Utilities Commission, the "CPUC", had long had safety regulation responsibilities for rail transit systems under state law, so the effect of this change in California was not as significant as it was in other states, such as Oregon, for example, in which there had not previously been a state role in rail safety regulation. The CPUC has had long-standing rules governing rapid transit systems, such as BART, and light rail systems, such as San Diego Trolley.

We thus have two regulatory systems in California - the FRA for railroads, and the CPUC for rail transit. The effect of this bifurcation in regulatory structure is important to the Transbay Terminal discussion, and the related issue of possible return of rail service to the Bay Bridge, since it means that very different operational regulations and physical requirements apply to passenger rail systems depending upon whether or not they are part of the nation's "general railroad system." Since the FRA's body of regulations under 49CFR run to more than 500 pages of small print, it is really not possible to offer any meaningful summary - the rules are simply too comprehensive and diverse. However, in terms of relevance to Terminal issues, the effect of the body of regulations is to prevent the co-mingling of commuter, or high speed or intercity railroad passenger trains on the same track as light rail trains. In the Terminal, this probably means different levels for the trackage of dissimilar systems.

FRA regulations are rooted in the railroad industry. Although they make provision for some aspects of regional passenger rail services, they essentially envision multiple-person crews, locomotives pulling cars, and passenger trains which run a certain risk of collision with each other and with freight trains. Many of the regulations deal with signalization of railroad lines, but there is an implicit assumption that signals and

operating procedures, and the human beings involved with them, will fail, as, indeed they have on many unfortunate occasions. Thus, a significant part of the body of regulations relates to structural requirements for rolling stock so that survivability in the event of an accident is maximized. Much of this regulation is not really applicable to light rail or rapid transit operation, but any co-mingling of operation automatically invokes them.

There has been significant recent discussion of placement of rails for passenger service on the Bay Bridge, and presumably into the Terminal, and as all readers of this working paper probably know, advisory referenda in several Central Bay Area cities have called for a study of this possibility. In that discussion, some have discussed the service to be provided on these rails as a new "Key System"-like light rail service, while others have suggested that they rails could be used to bring the Sacramento-Bay Area "Capitol Corridor" trains, or perhaps other commuter rail services, into San Francisco. While study of the issue may conclude that one or both of these objectives is feasible, it is important to recognize that under federal law, one set of tracks cannot be used both for light rail and for commuter/intercity railroad purposes. Once trackage is connected to the "general railroad system," FRA rules requiring equipment to have a specified collision survival strength, for example, will apply to all trains using the track; these standards, based on heavy steel locomotives used in mainline service, cannot be met by light rail equipment. For its part, the CPUC has generally frowned upon at-grade crossings of light rail lines and railroads. Thus, in San Jose, the light rail system passes under the ex-Southern Pacific Milpitas freight line in a North First Street underpass, and in Sacramento, the light rail system passes over the ex-Western Pacific mainline and the ex-Southern Pacific "Valley" mainline on new bridges.

B. Implications for Transbay Terminal Design

In taking the possibility of fitting passenger rail lines into the Terminal, the implication of regulatory restrictions on co-mingled light rail and "mainline" or FRA-compliant" services is that their simultaneous accommodation will require trackage on two levels. For example, if both a Bay Bridge light rail service and Caltrain were extended to the Terminal, the light rail service might use the present bus deck level, while Caltrain would probably be underground. On the other hand, if the Bay Bridge service were a "FRA-compliant" commuter-rail and mainline system, it would probably be desirable to try to accommodate both the Bridge and Caltrain service on the same level in order to make a track connection and make through-routed services possible.

Appendix B: Illustrative Comparison of Some Key Modal Variables

	Length	Weight Empty	Seats	Weight Loaded	Axles	Loaded Weight per Foot	Loaded Weight per Axle
Key Bridge Unit	111 feet	140,000 lbs.	124	172,550 lbs.	6	1555 lbs.	28,758 lbs.
IER Powered Coach	73 feet	117,400 lbs.	108	145,750 lbs.	4	1997 lbs.	36, 438 lbs.
SN Powered Coach	59 feet	102,000 lbs.	60	117,750 lbs.	4	1996 lbs.	29,438 lbs.
Portland Type 2 LRV	92 feet	109,000 lbs.	72	127,900 lbs.	6 (equiv.)	1390 lbs.	21,317 lbs.
BART C-Car	70 feet	63,800 lbs.	68	81,650 lbs.	4	1166 lbs.	20,413 lbs.
SEPTA Silver-liner IV	85 feet	120,000 lbs.	100 (or 120)	146,250 lbs.	4	1721 lbs.	36,563 lbs.
F59PH Diesel Loco.	58 feet	270,000 lbs.	n.a.	n.a.	4	4655 lbs.	67,500 lbs.
Acela Loco.	69.6 feet	180,000 lbs.	n.a.	n.a.	4	2586 lbs.	45,000 lbs.
Acela Trainset	663.7 feet	1,164k lbs.	304	1,200k lbs.	32	1800 lbs.	37,500 lbs.

Notes:

1. Misc. rolling stock assumptions:
   - Key System Bridge Unit from #105-124 series
   - IER powered coach from #362-367 series
   - SN powered coach from the Hall Scott series #1018-1025

2. Silverliner IV seats 120 in 3/2 seating, equivalent in 2/2 seating is about 100. Loaded weight calculated for 100 seated and 50 standing passengers.

3. Assumed per- passenger weight is 175 lbs. For passenger load, 150% of seated capacity is assumed, except that in the case of the Acela high-speed sets, a full seated load (304) is used.

Appendix C: Excerpts from Technical Memorandum on Two Types of EMU Equipment

Excerpts from technical memorandum from Dr. Norman Vutz, LTK Engineering Services, describing gradient and performance characteristics of two types of EMU equipment - the SEPTA "Silverliner IV" suburban electric cars operated in the Philadelphia metropolitan area, and the "South Shore" (Northern Indiana Commuter Transit District, or NICTD) cars operated between Chicago, Gary, Michigan City and South Bend:

- Both the SEPTA Silverliner IV and the NICTD South Shore cars are 85 feet long and weigh about 120,000 lbs. The SEPTA cars with 3+2 seating and no ADA toilets seated 120 originally, but are being reconditioned to 116 by elimination of 4 substandard seats in the center vestibule area. The NICTD cars with 2+2 seating, an ADA toilet, and center doors seat 96. I believe that the SEPTA cars have an initial rate of 2.5 mph/sec and a top speed of 100+ mph with 12.5 kV ac on the trolley wire. The NICTD cars have an initial rate of 2.75 mph/sec and a two car balancing speed of 72 mph at 1600 volts dc on the wire.

- The NICTD car is a dc clone of the AVCO/GE ac Silverliner IV. The NICTD specification was written around the AVCO/GE body and the GE Illinois Central Electric 1500 volt dc propulsion system. The Silverliner IV is a close cousin of the NJT Arrow II cars.... NICTD is now getting 8 more cars, but with Toshiba inverter propulsion for about $3 million each.

- One mile per hour per second of initial rate tractive effort is equivalent to climbing a 4.56% grade. Conversely, a 3.5% upgrade will "rob" a car of 0.77 mph/sec of initial rate. Electric cars typically accelerate at constant rate (initial rate) to a corner point speed, and then accelerate at constant power (decreasing rate) above the corner point speed. A car with an initial rate of 2.5 mph/sec and a corner point speed of 20 mph theoretically will balance at about 65 mph on a 3.5% upgrade. Wind resistance and similar factors that increase with speed will probably bring the actual up-hill speed to around 50 mph. Slippery rail and adhesion may be bigger problems than an adequate power/weight ratio in getting over the bridge.

Appendix D: Selected Leading Metropolitan Railroad Terminals

Illustrative Range of Track Capacity and Traffic Density (various years)

STATION	DATE OPENED (ORIGINAL)	NUMBER OF STATION TRACKS	NUMBER OF TRAINS PER DAY	NUMBER OF TRAINS PER TRACK PER DAY
Boston, North	1894	23	607	26.4
Boston, South	1899	28	817 (1915)	29.2
Chicago, Union	1925	21 (9+11+1)	389 (est. 1925)	18.5
Chicago, La Salle St.	1903	11	210	19.1
Chicago, North Western	1911	16	300	18.8
Cincinnati, Union Terminal	1933	16	147	9.2
Hoboken, Lackawanna	1907	14	263	18.8
Jersey City, Penn	1892	12	334	27.8
Kansas City, Union	1913	16	313	19.6
London, Waterloo	1848	21	1,262	60.1
London, Victoria	1862	17	1,106	65.1
London, London Bridge	1836	22	542	24.6
London, Paddington	1855	11	378	34.4
Montreal, Central	1943	16	146	9.1

New York, Grand Central	1913	67	520 (1944-47)	7.8
New York, Pennsylvania	1910	21	552 (1975)	26.3
Paris, St. Lazare	1860?	31	1,200 (est.)	38.7
Philadelphia, Broad Street	1893	16	574	35.9
Portland, Union	1894	7	75 (1914 est.)	10.7
St. Louis, Union	1894	32	322	10.1
Washington, Union	1907	26	244	9.4
San Francisco, Fourth Street	1975	12 (incl. storage)	66 (1998)	5.5
San Francisco, Transbay	1939	6	529 (loop, 1939)	88.2
San Jose, Diridon	1935	5 (12 w/storage)	80 (1998)	16 (6.7 w/storage)

Notes:

1. "Number of tracks" refers to tracks in use for revenue passenger handling at the station, and generally excludes, except as noted, other tracks used for storage, servicing, or handling of mail and express. Grand Central Terminal, New York, is, of course, the largest terminal by far in terms of number of tracks, although in most years, Penn Station has had more trains. St. Louis Union Station had the greatest number of tracks on a single level among American stations. Philadelphia Broad Street had the highest density of trains per track per day of any major metropolitan terminal with a stub arrangement.

2. Number of trains = departing moves plus arriving moves, except in the case of the Transbay Terminal, which, as a loop terminal, combined arrivals and departures into a single train movement, with a five-minute station stop in the peak. The Transbay figures are the total for all three operating railroads in February, 1939, as cited in Harre Demoro The Key Route (2 vols.) (1985)

3. Principal source for US stations is Carl W. Condit The Port of New York (2 vols) (1980 1981). Unless otherwise noted, the traffic figures presented for these stations are generally from 1911, in surveys conducted as part of the planning work carried out for the Grand Central Terminal project. Condit also cites John A. Droege Passenger Terminals and Trains (1916, repr. 1969). Condit The Railroad and the City (1977) was also used for Cincinnati data.

4. Condit provides his opinion that Chicago Union Station could "easily and safely" accommodate up to 300 trains on the north side, and 420 on the south (the station is essentially two back-to back stub terminals with one through track). This is equivalent to about 35 trains per track per day, which Condit regards as an approximate realistic maximum for a stub terminal under typical U.S. operating conditions. Carl W. Condit Chicago 1910--1929: Building, Planning and Urban Technology (1973)

5. At Portland Union Station, about 80% of the estimated volume of trains consisted of Southern Pacific electrified service handled on tracks 1 and 2 only. This represented an average daily train density of 30 on those tracks, which, though physically configured as through tracks, were essentially used as stub tracks.

6. Traffic data for London stations are for 1976; the original source is the London Transport Board, presented in Condit Port of New York. Alan A. Jackson London's Termini (1969) was also consulted. Figures for London Bridge Station are for originating and terminating trains only, and exclude through trains to and from the Charing Cross extension, probably another 800 per day or so.

7. Montreal data are from Michael Leduc Montreal Island Railway Stations (2 vols) (1994-96), and Anthony Clegg The Mount Royal Tunnel (1963).

8. Caltrain data are based on Peninsula Corridor Joint Powers Board "Draft Caltrain Rapid Rail Study," current timetable, and personal observations.

Appendix E: Text of 12th April 1999 Memorandum

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MEMORANDUM

TO: Transbay Terminal Study Team **PROJECT:** 2653

FROM: Thomas G. Matoff, Director - Transportation Planning

DATE: 12 April 1999

SUBJECT: **DRAFT** LRT/Bus Assumptions for Terminal Programming

The following is a summary of working assumptions made to permit a first rough-cut illustration of the potential impacts of a Transbay light rail service on the scope of Transbay bus service, and the results of those impacts for Terminal space requirements as a Terminal program is developed. There are obviously many ways to approach the design of a Transbay light rail network. These are working assumptions only, and are not a plan, proposal or recommendation of any kind. The concept documented in this memorandum is purely illustrative, and is suggested for purposes of discussion only insofar as it demonstrates the possible scale of a system which might result in potential space trade-offs in the Terminal itself.

A. Illustrative Transbay LRT System Concept

1. Description/Alignment

It is assumed that the system would originate at the Transbay Terminal, and operate across the Bay Bridge to the East Bay, where there would be three branches: Oakland-East 14th Street-Airport; Oakland-MacArthur; Berkeley-Telegraph Avenue. A station would be located at Yerba Buena Island, with connecting shuttles serving Yerba Buena and Treasure Islands. The first East Bay station would be located at or near the Oakland Army Base; additional station sites would be determined in the refinement of the Bridge Rail Feasibility Study.

The basic East Bay trunk of the system would run along 40th Street. The lines would branch from it as follows:

- The Oakland-East 14th Street-Airport Line would branch off at San Pablo Avenue, operate on San Pablo to Downtown Oakland at 14th, then south on Broadway and then east on 12th/East 14th to Seminary Avenue, south on Seminary to San Leandro Street, east along San Leandro Street to Hegenberger Road, then along Hegenberger to a terminal at Oakland International Airport. Connections with BART would be made in Downtown Oakland at 12th and Broadway (12th Street Oakland City Center Station), and at Coliseum/Airport Station.

- The Oakland-MacArthur Line would run east along 40th Street past BART MacArthur Station to Broadway, south on Broadway to MacArthur, then east/south along MacArthur Blvd to Mills College at Seminary Avenue. It would connect with BART at MacArthur Station.

- The Berkeley-Telegraph Avenue Line would leave 40th Street at Telegraph, turning north and running along Telegraph to the Cal campus at Bancroft, then west (two-way operation) on Bancroft to Oxford, north on Oxford to Center Street, and west on Center Street to Berkeley City Hall at Milvia Street. This line would connect with BART at both MacArthur and Downtown Berkeley Stations.

2. Service Concept

Each line would operate at 15-minute headways throughout the day (peak and base). On the common section of the trunk between San Francisco and 40th and San Pablo, the headways would be staggered to provide a consistent five-minute headway in both directions across the Bridge. Single cars would be operated in slack periods, with consists as long as three cars operated in peak periods (see below).

3. Vehicles

It is assumed that the light rail system would be equipped with Portland (TRI-MET) Type 2, 90-foot, low-floor light rail vehicles, or equivalent. It is assumed that modifications would be made, if necessary, to permit loaded trains to sustain 55 mph running on the bridge and its associated approach grades.

B. Assumed Light Rail/Bus Terminal Space Substitution

1. Concept Capacity

As noted, the concept provides for an aggregate 5-minute headway across the Bridge at all hours. In the peak one hour, in the peak direction, trains would be composed of three-car consists. This implies twelve 3-car trains in the peak one hour, or 36 cars operated through the Terminal in the peak one hour. It is assumed, conservatively, that each light rail vehicle will have one-third more capacity than one 60-foot articulated bus. Thus, 36 LRVs may be taken to represent at least the capacity of 1 1/3 (36) buses, or 36+12 = 48 articulated buses.

2. Impact on Bus Bay Requirements at the Terminal

As noted elsewhere, the Year 2020 projection for AC Transit Transbay peak bus flow is 153 buses per peak one hour in the peak direction. It was calculated that, assuming some increase in the intensity of use per bus bay, such a level of service would require 31 bays. Under the assumptions made here, light rail service would replace 48 of those 153 peak hour buses, or 48/153= 31.3%. A corresponding reduction of 31% in the required number of bus bays would be (.31)(31)=10, leaving 21 bays required for bus operation, plus the light rail service. This would represent, essentially, the equivalent of the present level of bus service (100 buses per peak hour, peak direction, using 21 - 24 bays), with the growth increment to 2020 primarily represented by the presence of light rail service.

	Vehicles: Peak One Hour, Peak Direction	Terminal Space
Current	100 buses	21 - 24 bays
Year 2020 Projected without LRT	153 buses	31 bays
Year 2020 projected with LRT	105 buses 36 LRVs	21 bays 2 berths for 3-car trains

C. Physical Arrangements in the Terminal

1. Double Track in Terminal

The assumption made to further the space assessment for the Terminal with Transbay bus and light rail operation is based on the sharing of one Terminal platform and its associated bus bay and travel lane. This shared operation is feasible with light rail systems, and is based on the assumption that street-type trackage, such as girder rail, and its associated special work, would be installed in the bus roadway, with the top of rail flush with the roadway surface.

It is further assumed that the Bridge trackage would be a double-track installation, with one track signaled for, and regularly operated in each direction. It is assumed that the loop arrangement would be retained at the Terminal. Approaching the Terminal, the inbound track would divide into two tracks, which would be carried through the Terminal area. Except when standing at the platform itself, most use by arriving or departing trains would be made of the track located in the "through lane" part of the roadway. Leaving the Terminal to approach the Bridge, the two tracks would converge into the single eastbound mainline.

In the space analysis being conducted for purposes of Terminal programming, AC Transit's bus transit design criteria are being used; these are generally appropriate for light rail in this circumstance as well. AC's criteria call for a roadway with a minimum width of 25 feet between the platform-side curb protrusion of the sawtooth bus bays and the curb on the opposite side of the roadway. The 25-foot width is sufficient for a double-track light rail installation, and the level of service described above (5-minute headway) can be accommodated on the track in the "through" lane, which will not be blocked by the ends of articulated buses sitting in the bus bays.

2. Platform Space

AC Transit's design criteria provide for 85-foot platform length for bus bays accommodating articulated buses. The reduction of bus bays by 10, noted above, would therefore reduce the platform length required for buses by 850 feet. A flat platform curb for two light rail trains would be required in place of this bus platform. Assuming the possibility of two three-car trains in the terminal simultaneously, and the use of Portland Type 2 low-floor cars at a length of 90 feet per car, each light rail "berth" would require 270 feet. In order to permit independent access to and exit from either berth, a scissors crossover would be placed between the two berths, and a facing crossover following the second berth (in the direction of travel). The intermediate scissors crossover would require some additional length, and for the moment it will be assumed that this would mean about 100 additional feet of length between the two berths. (This is a change from the team discussion of 12 April). Therefore, the assumed total length of the platform space required for light rail would be the two three-car trains, or 540 feet (2 x 270 feet), plus a nominal 100 feet, for a total of 640 feet.

This is an estimated net reduction in required platform length for comparable delivered capacity of approximately 210 feet (850 feet saved from ten bus bays, but adding back 640 feet required for light rail).

Taking the overall sawtooth-bay platform and roadway width required in AC Transit's design criteria of 41 feet, the net reduction in required Terminal area would be (41 feet)(210 feet)=8,120 square feet.

Appendix F: Bay Bridge Rail Study Team

Nelson/Nygaard Consulting Associates:	Transit operations, project direction, and consensus building
Simon Martin-Vegue Winkelstein Moris:	Coordination with the Tranbay Terminal Improvement Project, consensus-building and urban design
LTK Engineering Services:	Transit operations
Fehr & Peers, Inc.:	Traffic engineering
Ove Arup & Partners:	Structural and transit engineering
Pacific Transit Management:	Transit demand and cost modeling