Submitted To

Rocky Mountain Rail Authority

November 2008

High Speed Rail Feasibility Study
Alternatives Development Report

Submitted By
TEMIS
Transportation Economics & Management Systems, Inc.
in association with
Quandel Consultants, LLC
Table of Contents

1 Introduction ........................................................................................................................... 1
2 Stations Proposed.............................................................................................................. 3
3 Generic Technologies.......................................................................................................... 4
   3.1 Generic Categories ........................................................................................................ 5
   3.2 Generic Categories - Conclusions ................................................................................ 10
4 Representative Routes...................................................................................................... 12
5 Conclusion .......................................................................................................................... 19
1 Introduction

The purpose of the report is to establish the “base case” alternatives for both the technology and routes to be evaluated as part of the RMRA High Speed Rail Feasibility Study. For each alternative the aim is to produce a reasonable representative option for the type of technology. In the case of the slower speed alternatives (79-110 mph), the most effective option is to use existing railroad rights-of-way and where possible (where freight rail traffic is limited) to comingle with the freight traffic. As speeds and frequency of passenger rail service increases the ability to first comingle and second use existing railroad rights-of-way becomes more limited. Of course commingling or use of the freight railroads right-of-way, may well still occur (at lower speeds) in urban areas to get access to downtown stations, but away from the urban area it is likely to require a “greenfield” route as high speed rail operations needs long stretches of straight track and very gentle curves to get the benefit of the high speed. A greenfield route will frequently have less stations as the distance needed to “get up to speed” and the distance required to stop is much longer. In general, faster systems have fewer stations stops. See Exhibit 1-1. However, a compromise may be needed to ensure all key communities are served, but in each case it’s a trade off between end-to-end speed and connecting communities. Each station stop takes three to seven minutes so multiple stops soon dramatically increase end-to-end running times.

Exhibit 1-1: Station Spacing Increasing with Speed

Increased Speed Means Greater Station Spacing
In terms of the framework, three sets of scenarios need to be identified:

1. Station stops
2. Representative technologies
3. Representative routes
2 Stations Proposed

For the purposes of this study, Exhibit 2-1 shows the potential stations that can be served. The large green stations show what must be served, the smaller red stations show what is thought to be desirable if possible. The service to the small red stations is likely to be more limited than the green stations and may only receive four to six trains per day in both directions compared with the twelve to twenty-four trains per day in both directions for the green stations.

The selection of station stops was largely market driven (i.e., the stop represents a major attraction or destination. However, the study team received input on acceptability from the public outreach workshops, and both the I-70 Coalition and Colorado urban MPO’s as well as other major transportation authorities such as Denver International Airport, and RTD.
3 Generic Technologies

For evaluation purposes, vehicle technologies will be clustered into five generic “technology categories,” where each category corresponds to a specific vehicle technology and performance capability. The five categories that will be used as the basis of the evaluation are shown in Exhibit 3-1.

Exhibit 3-1: Generic Technology Categories

<table>
<thead>
<tr>
<th></th>
<th>79-mph</th>
<th>110-130 mph</th>
<th>150-220 mph</th>
<th>250-300 mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Maglev</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

By defining “Generic” categories of equipment options, route evaluations will be valid for a range of equipment options rather than only for one specific manufacturers’ train. This ensures the ability to maintain a competitive equipment procurement process, since several manufacturers could meet the performance criteria that will be established for each generic category. Reasonable conservatism in the equipment specification also ensures that the operational analysis and financial projections will be conservative, increasing confidence that the implementation plan can be realized in practice.

As shown in Exhibit 3-1, there are three categories to reflect rail (steel wheel) vehicles, while two categories are for maglev technologies. For both rail and maglev, an important criterion for this study is that the technology must be proven in revenue service.

- All three kinds of steel wheel vehicles are in revenue service today.
- With respect to high-speed maglev, the Transrapid system is in revenue service today. The Tobu Kyuryo Line in Nagoya, Japan demonstrates the feasibility of the low-speed maglev concept that was envisioned in the earlier 2004 Colorado Maglev Study.

A key requirement of the study is that the proposed technologies should all be capable of receiving required regulatory approvals within the implementation time scales of the project. This section will assess relevant proven technology options and their potential speed, focusing on existing technologies that have been proven in actual revenue service, and clustering the technologies into Generic Categories.
3.1 Generic Categories

This section addresses the three speed ranges that characterize rail technology capabilities, as well as the two maglev categories. Within these ranges any number of specific technologies could be chosen depending on how practical and cost effective they are for achieving any given speed.

**Conventional Rail** - 79-mph or less: “Conventional” trains, as shown in Exhibit 3-2, can operate at up to 79-mph on existing freight tracks. 79-mph represents the highest speed at which trains can legally operate in the United States without having a supplementary cab signaling system on board the locomotive. The key characteristics of these trains are that they are generally:

- Designed for economical operation at conventional speeds
- Can be diesel or electric powered
- Non-tilting for simplified maintenance

Because of the focus on economy these trains sacrifice performance, for example, the decision to employ non-powered “Cabbage Cars” rather than powered locomotives on Talgo trains currently operated by Amtrak in the Pacific Northwest. Double deck trains such as operated in California also seek to minimize cost rather than maximize speed -- but in the process, they sacrifice the time-competitiveness of the rail service as compared to driving, except in the most extreme congested highway conditions.

Both FRA compliant and non-compliant equipment fall into this category. Representative trains include the Conventional Amtrak train, compliant Colorado Railcar DMU and non-compliant Stadler FLIRT EMU, all pictured in Exhibit 3-2 below.

![Exhibit 3-2: Conventional Rail – Representative Trains](image-url)
High Speed Rail - 110-130 mph: A 110-to-130-mph service can often be incrementally developed from an existing conventional rail system by improving track conditions, adding a supplementary Positive Train Control safety system, and improving grade crossing protection. The addition of tilt capability, by allowing trains to go around curves faster, has proven to be very effective for improving service on existing track, often enabling a 20-30% reduction in running times. The key characteristics of these trains are that they are generally:

- Designed for operation above 100-mph on existing rail lines
- Can be diesel or electric powered
- Usually tilting unless the line is very straight

In the United States, safety regulations favor deployment of 110-mph service because grade separation of highway crossings is required at 125-mph, at significant additional cost. 110-mph service provides a low cost infrastructure option by using existing railroad rights-of-way. Systems operating in this speed range are generally able to produce auto-competitive travel times, and are therefore often able to generate sufficient revenues to cover their operating costs.

Both FRA compliant and non-compliant equipment fall into this category. It has been estimated that the non-compliant trains could be made Tier I compliant for operation up to 125-mph for an average 7-10% weight penalty. Representative trains include the Talgo T-21 diesel locomotive hauled trains, the Flexliner DMU, the X-2000 Electric locomotive hauled train and the ICE-T EMU, all pictured in Exhibit 3-3 below. It should be noted that the ICE-T is actually a higher-powered train that is capable of 186-mph on new dedicated tracks, but it is included in this category because of its tilting capability, which enables a significant speed improvement on conventional rail lines.

Exhibit 3-3: High Speed Rail – Representative Trains
**High Speed Maglev** - 110-130 mph. For this evaluation, the 2004 *Colorado Maglev* proposal represents the High Speed category. At present, this type of system has been implemented only in a low-speed urban transit application. Whereas high-speed maglev systems place the linear motor on the guideway (LSM), low-speed systems place the motor on board the vehicle (LIM) to reduce cost. The Japanese HSST is the best example of this type of urban Maglev with a 5.5-mile operating line in Nagoya, Japan (see Exhibit 3-4). American Maglev and General Atomics both have similar urban maglev concepts on test tracks. The current HSST was designed as an urban transit mode, not as a high-speed system. It has a top speed of 65-mph\(^1\). The HSST technology would have to be adapted significantly to meet the speed requirements needed for High Speed Rail service in Colorado. The key characteristics of these trains are:

- They are High-Speed derivatives of Urban Maglev designs, as opposed to systems that were designed from the beginning to go as fast as possible.
- The HSST urban maglev system is operational and others are on test tracks, but the modifications needed to prove high-speed capability are still in the R&D phase.
- For evaluation purposes however, we are treating these systems as if they were operational today, on the basis of the system specifications as outlined in the 2004 *Colorado Maglev Study*.

---

**Exhibit 3-4: High Speed Maglev - Representative Trains**

---

Very High Speed Rail - 150-220 mph: Speeds above 150-mph generally require development of new high-speed alignments along with the deployment of powerful electric trains. These services are usually very popular which has led to the development of the double-decked TGV train. However, the most recent trend in development of the highest speed trains is a move towards Electric Multiple Unit (EMU) technology, such as the German ICE-3 train shown in Exhibit 3-5.

Rather than using locomotives, the EMU design places traction motors underneath each individual railcar. This has the advantage of eliminating the dead weight of the locomotive, increasing the number of traction motors leading to an increase in power, improving adhesion since half or more of the train's axles are powered, and making more effective use of station platform length. However, when high-speed services are extended beyond the reach of the high-speed tracks using conventional lines, tilting capability can prove very advantageous, which has led to the development of the ICE-T EMU pictured earlier. The key characteristics of these trains are:

- High-Powered for operation at 150-mph or higher on new lines.
- Electric only
- For trains that operate on conventional tracks beyond the new lines, tilting versions of Very High Speed trains have been developed to allow them to go around curves faster.

The only existing Tier II compliant train is Amtrak's Acela express, but it has been estimated that the European or Japanese locomotive-hauled trains could be adapted to Tier II compliance for an approximate 10% weight penalty. Some representative trains are shown in Exhibit 3-5.

Exhibit 3-5: Very High Speed Rail - Representative Trains
Ultra High Speed Maglev - 250-300 mph: For speeds above 250-mph the only current candidate is Maglev technology. (Rail has demonstrated speeds above 250-mph but only on experimental trial runs. However such speeds are routinely attained by the Shanghai airport maglev in revenue service, as shown in Exhibit 3-6.) This system is fundamentally different from a rail technology in that it does not use a steel wheel/steel rail contact, but rather uses magnetic levitation to float above a concrete guideway, as well as to propel the train. For high-speed maglev, only Siemens’ Transrapid shown in Exhibit 3-6 is in commercial operation. Maglev trains are capable of rapid acceleration up to their design limits and typically operate in consists of two to five cars. Seating capacity is generated by operating the trains at higher frequency than normal steel wheel/steel rail trains, or by linking car sets together if platform lengths permit. The key characteristics of these trains are:

- They were designed from the beginning for Ultra High-Speed.
- There is only one existing operational system (Transrapid) in this class today although there are additional High Speed concepts in R&D throughout the world.
- For evaluation purposes the Transrapid system will be assumed.

Exhibit 3-6: Ultra High Speed Maglev– Representative Train
3.2 Generic Categories - Conclusions

The selection of a “Generic” train technology must necessarily be conservative for summarizing the performance capabilities of that equipment classification. For rail equipment, self-propelled equipment is generally lighter and can have more installed power per ton. Therefore, in general DMU or EMU equipment outperforms locomotive hauled options. Accordingly for selection of a Generic train, the general rule is to select for evaluation the locomotive hauled option, but because of the possibility of gradients exceeding 4% on the I-70 corridor, one EMU option needs to be retained as well. With the exception of I-70 grades exceeding 4%, this preserves the ability to consider either locomotive hauled or self-propelled equipment in a subsequent equipment procurement process, since a broad array of equipment options will be capable of meeting the performance requirements for the technology category.

In summary, for the purpose of this feasibility study, it is proposed to adopt the technologies shown in Exhibit 3-7 as the recommended “Generic” representatives of each technology category.
<table>
<thead>
<tr>
<th>Category</th>
<th>Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Rail 79-mph</td>
<td>Amtrak Train</td>
<td>A conventional, non-tilting passenger train, Diesel locomotive hauled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(FRA Tier I compliant)</td>
</tr>
<tr>
<td>High Speed Rail 110-130 mph</td>
<td>Talgo T-21</td>
<td>Diesel locomotive-hauled (FRA Tier I compliant, Electric-hauled option</td>
</tr>
<tr>
<td></td>
<td></td>
<td>also available)</td>
</tr>
<tr>
<td>High Speed Maglev 110-130 mph</td>
<td>Colorado Maglev</td>
<td>(FRA Non-compliant)</td>
</tr>
<tr>
<td>Very High Speed Rail 150-220 mph</td>
<td>Eurostar</td>
<td>Electric locomotive-hauled with booster under first and last car (FRA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tier II compliant with 10% weight penalty)</td>
</tr>
<tr>
<td>Ultra High Speed Maglev 250-300 mph</td>
<td>ICE-T EMU</td>
<td>Retained for grades exceeding 4% (FRA Tier I/II compliant with 7-10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weight penalty, same performance as Eurostar under 4% grade)</td>
</tr>
<tr>
<td></td>
<td>Transrapid Maglev</td>
<td>(FRA Non-compliant)</td>
</tr>
</tbody>
</table>
4 Representative Routes

The representative routes are depicted on the following maps:

1. I-25 North of Denver
2. I-25 South of Denver
3. I-70 East of Avon
4. I-70 West of Avon
5. Denver Metro North

The representative routes north of Denver, as shown on Map #1 include the UPRR Greeley subdivision from the Denver area to Greeley; the Great Western Railroad subdivision from Greeley to Fort Collins; and the BNSF railroad from Fort Collins to Cheyenne. The representative routes also include a route within or contiguous to the BNSF right of way through Boulder, Longmont, and Fort Collins to Cheyenne. For access to DIA airport, the representative route is within or contiguous to the BNSF Brush subdivision right of way. For access from DIA to the north, this route continues north to E-470; a greenfield segment within or contiguous to the I-25 corridor; and a greenfield segment within or contiguous to the I-25 corridor to Cheyenne.

The representative routes south of Denver, as shown on Map #2, include the joint line rights of way either owned by BNSF and UPRR from Denver to Trinidad. Greenfield segments are also shown from Castle Rock to Monument; and from Monument to Colorado Springs including a route either within or contiguous to the joint line in the Colorado Springs area; from Colorado Springs to Pueblo including a segment either within or contiguous to the existing railroad right of way in the Pueblo area; and from Pueblo to Walsenburg and Trinidad.

The representative routes for I-70 East of Avon from the Golden area, as shown on Map #3, include a segment up the Clear Creek canyon that is either within or contiguous to the right of way of US 6 to the west intersection of I-70 and US 6; and an alternative route on I-70 via the El Rancho area to the west intersection of I-70 and US 6. Both routes feature a connection to Black Hawk either along SH 119 from US 6 or a tunnel from I-70. From the west intersection of I-70 and US 6, the representative route is either within or contiguous to the I-70 corridor to Idaho Springs and Georgetown. At Georgetown, the route continues either within the I-70 right of way or via a new tunnel on the north side of I-70. This tunnel would begin east of Georgetown and exit on the south side of I-70 west of Silver Plume. The route continues either within or contiguous to the I-70 corridor to east of the Eisenhower Johnson Memorial Tunnel. At this point, the route either continues through a new bore west either within or contiguous to the I-70 Corridor to Silverthorne, Dillon and the Keystone area or through a new North Fork Tunnel to Keystone area with a branch line to Silverthorne and Dillon. From the Keystone area the route continues to the Breckenridge area near SH 9 with a branch connection to Breckenridge. From this intersection of the route with SH90, the route either continues through a new Breckenridge tunnel to Copper Mountain or north to Frisco and continues either within or contiguous to the I-70 corridor to Copper Mountain. From Copper Mountain, the representative route either is within or contiguous to the I-70 corridor to Vail or proceeds south along the SH91 with a segment through the National Forest to the UPRR Tennessee
Pass subdivision at Pando. The route proceeds within or contiguous to the UPRR right of way north to Minturn with a branch connection to Vail. The route continues to Avon either within or contiguous to the UPRR right of way.

The representative routes for I-70 West of Avon, as shown on Map #4 include a segment either within or contiguous to the UPRR right of way, as well as the I-70 corridor from Avon to Glenwood Springs to Grand Junction. The representative routes west of Avon also include a connection to Yampa, Steam Boat Springs, and Craig either within or contiguous to the UPRR right of way from Dotsero to Bond to Craig, with a potential alternative route from Wolcott to Bond either within or contiguous to SH131. These representative routes also include a segment to Aspen either using a tunnel from the Gypsum area to the Basalt area connecting to the Roaring Fork Transit Authority right of way from Glenwood Springs to Aspen or a segment from the UPRR right of way at Glenwood Springs onto the right of way of the RFTA to Aspen.

The representative routes for the Denver Metro area, as shown on Map #5, encompass the range of preliminary scenarios. The representative routes include a connection to the Denver International Airport either within or contiguous to the BNSF Brush subdivision to the 96th Street area proceeding westerly either within or contiguous to property associated with the Rocky Mountain Arsenal to DIA. The BNSF Brush subdivision and the UPRR Greeley subdivision provide representative routes from the Downtown and DIA to the North. The Denver Metro representative routes also include the use of the BNSF and UPRR rights of way within the downtown area. Access to a downtown station could include tunnels and flyovers to ensure efficient operations. For access to the south, the representative route is either within or contiguous to the joint line of UPRR and BNSF. The representative routes to Golden include a segment within or contiguous to either US 6, I-70, I-76/I-70, or the Golden Subdivision of the BNSF.
I-70 Tunnel Options

1.) Georgetown
2.) North Fork
3.) Breckenridge
4.) Aspen
5.) Black Hawk

* The need for additional tunnels will be evaluated in the alternative development phase

Map #3
I-70 East of Avon

Legend
Stations
- Main Station
- Secondary Station

Existing Railroad
Highways
I-70

High Speed Rail Alignment
Off I-70 Corridor Route
Tunnel

Data source: Colorado DOT
Map prepared: November 13, 2008

I-70 Tunnel Options

1.) Georgetown
2.) North Fork
3.) Breckenridge
4.) Aspen
5.) Black Hawk

* The need for additional tunnels will be evaluated in the alternative development phase
I-70 West of Avon

Map #4

Legend

Stations
- Main Station
- Secondary Station

Existing Railroad

Highways

I-70

High Speed Rail Alignment

Off I-70 Corridor Route

Tunnel

Craig
Steamboat Springs
Aspen
Craig/Steamboat Springs Route

131 Route

I-70 Tunnel Options
1.) Georgetown
2.) North Fork
3.) Breckenridge
4.) Aspen
5.) Black Hawk
* the need for additional tunnels will be evaluated in the alternative development phase

Existing Railroad

Highways

I-70

Aspen Tunnel
L: 51,000 ft

Craig
Steamboat Springs
Aspen
Craig/Steamboat Springs Route

131 Route

I-70 Tunnel Options
1.) Georgetown
2.) North Fork
3.) Breckenridge
4.) Aspen
5.) Black Hawk
* the need for additional tunnels will be evaluated in the alternative development phase

Existing Railroad

Highways

I-70

Aspen Tunnel
L: 51,000 ft

Craig
Steamboat Springs
Aspen
Craig/Steamboat Springs Route

131 Route

I-70 Tunnel Options
1.) Georgetown
2.) North Fork
3.) Breckenridge
4.) Aspen
5.) Black Hawk
* the need for additional tunnels will be evaluated in the alternative development phase
5 Conclusion

Following the evaluation of technology and route options a preliminary set of alternatives were defined as shown in Exhibit 5-1 to 5-3. The options include:

- 79-mph Conventional Diesel Technology in the I-25 North/South corridors, with and without R2C2 program.
- 110-mph High Speed Diesel tilt technology in the I-25 North/South corridors, with and without the R2C2 program.
- 125-mph Colorado Maglev technology in the I-25 North/South and I-70 East/West corridors.
- 150-mph Electric Locomotive technology in the I-25 North/South and I-70 East/West corridors.
- 220-mph Electric EMU technology in the I-25 North/South and I-70 East/West corridors.
- 300-mph Transrapid Maglev technology in the I-25 North/South and I-70 East/West corridors.

The results of these 36 segment options shown in Exhibit 5-1 will be evaluated to identify the preferred Steel Wheel and Maglev Alternatives.
### Exhibit 5-1: Proposed Preliminary Scenarios

<table>
<thead>
<tr>
<th>Corridor</th>
<th>I-25 North</th>
<th>I-25 South</th>
<th>I-70 (Avon and East)</th>
<th>I-70 (Avon and West)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (a)</td>
<td><img src="image1.png" alt="Image" /> Diesel Technology</td>
<td><img src="image2.png" alt="Image" /> Diesel Technology</td>
<td><img src="image3.png" alt="Image" /> Diesel Technology</td>
<td><img src="image4.png" alt="Image" /> Diesel Technology</td>
</tr>
<tr>
<td></td>
<td>79 mph Track Speed</td>
<td>79 mph Track Speed</td>
<td>Existing Rail, without R2C2</td>
<td>Existing Rail, without R2C2</td>
</tr>
<tr>
<td></td>
<td>Existing Rail, without R2C2</td>
<td>Existing Rail, without R2C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (b)</td>
<td><img src="image5.png" alt="Image" /> Diesel Technology</td>
<td><img src="image6.png" alt="Image" /> Diesel Technology</td>
<td><img src="image7.png" alt="Image" /> Diesel Technology</td>
<td><img src="image8.png" alt="Image" /> Diesel Technology</td>
</tr>
<tr>
<td></td>
<td>79 mph Track Speed</td>
<td>79 mph Track Speed</td>
<td>Existing Rail, with R2C2</td>
<td>Existing Rail, with R2C2</td>
</tr>
<tr>
<td></td>
<td>Existing Rail, with R2C2</td>
<td>Existing Rail, with R2C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 (a)</td>
<td><img src="image9.png" alt="Image" /> Diesel Technology</td>
<td><img src="image10.png" alt="Image" /> Diesel Technology</td>
<td><img src="image11.png" alt="Image" /> Diesel Technology</td>
<td><img src="image12.png" alt="Image" /> Diesel Technology</td>
</tr>
<tr>
<td></td>
<td>110 mph Track Speed</td>
<td>110 mph Track Speed</td>
<td>Existing Rail, without R2C2</td>
<td>Existing Rail, without R2C2</td>
</tr>
<tr>
<td></td>
<td>Existing Rail, without R2C2</td>
<td>Existing Rail, without R2C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 (b)</td>
<td><img src="image13.png" alt="Image" /> Diesel Technology</td>
<td><img src="image14.png" alt="Image" /> Diesel Technology</td>
<td><img src="image15.png" alt="Image" /> Diesel Technology</td>
<td><img src="image16.png" alt="Image" /> Diesel Technology</td>
</tr>
<tr>
<td></td>
<td>110 mph Track Speed</td>
<td>110 mph Track Speed</td>
<td>Existing Rail, with R2C2</td>
<td>Existing Rail, with R2C2</td>
</tr>
<tr>
<td></td>
<td>Existing Rail, with R2C2</td>
<td>Existing Rail, with R2C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (a)</td>
<td><img src="image17.png" alt="Image" /> Maglev Technology</td>
<td><img src="image18.png" alt="Image" /> Maglev Technology</td>
<td><img src="image19.png" alt="Image" /> Maglev Technology</td>
<td><img src="image20.png" alt="Image" /> Maglev Technology</td>
</tr>
<tr>
<td></td>
<td>125 mph Track Speed</td>
<td>125 mph Track Speed</td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-70 Highway Footprint Alignment</td>
</tr>
<tr>
<td></td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-25 Highway Corridor Alignment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image21.png" alt="Image" /> Maglev Technology</td>
<td><img src="image22.png" alt="Image" /> Maglev Technology</td>
<td><img src="image23.png" alt="Image" /> Maglev Technology</td>
<td><img src="image24.png" alt="Image" /> Maglev Technology</td>
</tr>
<tr>
<td></td>
<td>125 mph Track Speed</td>
<td>125 mph Track Speed</td>
<td>I-70 Highway Footprint Alignment</td>
<td>I-70 Highway Footprint Alignment</td>
</tr>
<tr>
<td></td>
<td>I-70 Highway Footprint Alignment</td>
<td>I-70 Highway Footprint Alignment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corridor</td>
<td>I-25 North</td>
<td>I-25 South</td>
<td>I-70 (Avon and East)</td>
<td>I-70 (Avon and West)</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>Alternative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (b)</td>
<td><img src="image1.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image2.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image3.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image4.png" alt="Image" /> • Maglev Technology</td>
</tr>
<tr>
<td></td>
<td>Max. 125 mph Track Speed</td>
<td>Max. 125 mph Track Speed</td>
<td>Max. 125 mph Track Speed</td>
<td>Max. 125 mph Track Speed</td>
</tr>
<tr>
<td></td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-70 Highway Corridor Alignment</td>
<td>I-70 Highway Corridor Alignment</td>
</tr>
<tr>
<td>3 (c)</td>
<td><img src="image1.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image2.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image3.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image4.png" alt="Image" /> • Maglev Technology</td>
</tr>
<tr>
<td></td>
<td>Max. 125 mph Track Speed</td>
<td>Max. 125 mph Track Speed</td>
<td>Max. 125 mph Track Speed</td>
<td>Max. 125 mph Track Speed</td>
</tr>
<tr>
<td></td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-25 Unconstrained Alignment</td>
<td>I-70 Unconstrained Alignment</td>
<td>I-70 Unconstrained Alignment</td>
</tr>
<tr>
<td>4</td>
<td><img src="image1.png" alt="Image" /> • Electric Technology</td>
<td><img src="image2.png" alt="Image" /> • Electric Technology</td>
<td><img src="image3.png" alt="Image" /> • Electric Technology</td>
<td><img src="image4.png" alt="Image" /> • Electric Technology</td>
</tr>
<tr>
<td></td>
<td>Max. 150 mph Track Speed</td>
<td>Max. 150 mph Track Speed</td>
<td>Max. 150 mph Track Speed</td>
<td>Max. 150 mph Track Speed</td>
</tr>
<tr>
<td></td>
<td>Existing Rail, with R2C2</td>
<td>Existing Rail, with R2C2</td>
<td>I-70 Unconstrained Alignment</td>
<td>I-70 Unconstrained Alignment</td>
</tr>
<tr>
<td>5</td>
<td><img src="image1.png" alt="Image" /> • Electric Technology</td>
<td><img src="image2.png" alt="Image" /> • Electric Technology</td>
<td><img src="image3.png" alt="Image" /> • Electric Technology</td>
<td><img src="image4.png" alt="Image" /> • Electric Technology</td>
</tr>
<tr>
<td></td>
<td>Max. 220 mph Track Speed</td>
<td>Max. 220 mph Track Speed</td>
<td>Max. 220 mph Track Speed</td>
<td>Max. 220 mph Track Speed</td>
</tr>
<tr>
<td></td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-25 Unconstrained Alignment</td>
<td>I-70 Unconstrained Alignment</td>
<td>I-70 Unconstrained Alignment</td>
</tr>
<tr>
<td>6 (a)</td>
<td><img src="image1.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image2.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image3.png" alt="Image" /> • Maglev Technology</td>
<td><img src="image4.png" alt="Image" /> • Maglev Technology</td>
</tr>
<tr>
<td></td>
<td>Max. 300 mph Track Speed</td>
<td>Max. 300 mph Track Speed</td>
<td>Max. 300 mph Track Speed</td>
<td>Max. 300 mph Track Speed</td>
</tr>
<tr>
<td></td>
<td>I-25 Highway Corridor Alignment</td>
<td>I-25 Unconstrained Corridor Alignment</td>
<td>I-70 Highway Corridor Alignment</td>
<td>I-70 Highway Corridor Alignment</td>
</tr>
</tbody>
</table>
## Exhibit 5-2: Proposed Preliminary Scenarios - Technology Definitions

### RMRA Technology - Definitions

<table>
<thead>
<tr>
<th>Corridor</th>
<th>I-25 North</th>
<th>I-25 South</th>
<th>I-70 (Avon and East)</th>
<th>I-70 (Avon and West)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Maglev Technology</td>
<td>• Maglev Technology</td>
<td>• Maglev Technology</td>
<td>• Maglev Technology</td>
</tr>
<tr>
<td></td>
<td>• Max. 300 mph Track Speed</td>
<td>• Max. 300 mph Track Speed</td>
<td>• Max. 300 mph Track Speed</td>
<td>• Max. 300 mph Track Speed</td>
</tr>
<tr>
<td></td>
<td>• I-25 Highway Corridor Alignment</td>
<td>• I-25 Unconstrained Alignment</td>
<td>• I-70 Unconstrained Alignment</td>
<td>• I-70 Unconstrained Alignment</td>
</tr>
</tbody>
</table>

### Conventional Rail, FRA Compliant, Diesel Powered, Locomotive Pulled or Diesel Multiple Unit, Non-Tilt

- High Speed Rail, FRA Compliant Diesel Powered, Locomotive Pulled or Diesel Multiple Unit, with Tilt
- Vehicle and performance capability as defined by the 2004 FTA Colorado Maglev Project Study using an advanced vehicle derived from the Japanese HSST technology. It is also assumed that the American Maglev and General Atomics Maglev passenger vehicles will be in this technology and performance category.

### High Speed Rail, FRA Compliant, Electric Powered, Locomotive Pulled or Electric Multiple Unit, with Tilt

- High Speed Rail, FRA Compliant, Electric Powered, Locomotive Pulled or Electric Multiple Unit, with Tilt
- Very High Speed Rail, FRA Compliant, Electric Powered, Locomotive Pulled or Electric Multiple Unit, with Tilt
- Vehicle technology and performance capability based on the Siemens Transrapid maglev vehicle technology.
### Exhibit 5-3: Proposed Preliminary Scenarios - Route Definitions

**RMRA Route - Definitions**

<table>
<thead>
<tr>
<th></th>
<th>RMRA Route</th>
<th>Existing Rail</th>
<th>Existing Rail with R2C2</th>
<th>I-25 Corridor Footprint</th>
<th>I-25 Corridor Alignment</th>
<th>I-25 Unconstrained Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I-25 North-South Routes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Rail</td>
<td></td>
<td>Rail alignment largely within the existing BNSF and UP railroad right of ways, but allowing freight traffic within those rights of way.</td>
<td>Rail alignment largely within the existing BNSF and UP railroad rights of way, but under the assumption that thru freight traffic is moved to another alignment further east as evaluated in the R2 C2 Study.</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Existing Rail with R2C2</td>
<td></td>
<td>Rail alignment largely within the existing BNSF and UP railroad rights of way, but under the assumption that thru freight traffic is moved to another alignment further east as evaluated in the R2 C2 Study.</td>
<td>Rail alignment following the I-25 highway right of way including, but not limited to the shoulder to shoulder actual width of the existing highway. The alignment can be on-grade, elevated or tunneled to make the best use of the highway right of way in order to minimize grade changes and maximize curve distances.</td>
<td></td>
<td></td>
<td>Rail alignment capable of being within the highway corridor alignment as defined above, but can also be on-grade, elevated or tunneled in truly &quot;Greenfield&quot; areas completely outside the highway corridor, including areas to the east outside the I-25 highway right of way and outside the freight railroad rights of way. This is the most unconstrained rail alignment designed to minimize grade changes and maximize curve distances and still reach the critical Front Range passenger markets.</td>
</tr>
<tr>
<td>I-25 East-West Routes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Rail</td>
<td></td>
<td>West of Avon the rail alignment will parallel the existing UP railroad right of ways, but allowing for freight traffic within those rights of way and deviating where there is an advantage.</td>
<td>Elevated rail alignment within the should to shoulder actual width of the existing highway and completely within the highway right of way. The structured rail alignment can vary between above the highway shoulders, above the highway lanes or above the highway median to minimize grade changes and maximize curve distances. It will also include on-grade sections in tunnels parallel to the current highway tunnels.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Rail with R2C2</td>
<td></td>
<td>Elevated rail alignment within the should to shoulder actual width of the existing highway and completely within the highway right of way. The structured rail alignment can vary between above the highway shoulders, above the highway lanes or above the highway median to minimize grade changes and maximize curve distances. It will also include on-grade sections in tunnels parallel to the current highway tunnels.</td>
<td>Elevating from the structures above the highway right of way will be converted into tunnels to allow other highway and utility alignments to be used in the corridor.</td>
<td></td>
<td></td>
<td>Railway alignment capable of being in the highway footprint described above but can also be on-grade, elevated, or tunneled in areas outside the actual highway footprint of way in order to make use of the corridor valley and hillides to minimize grade changes and maximize curve distances. A highway corridor alignment will remain within the primary I-70 highway corridor and does not include adjacent highway corridor right of way such as US 6, US 40, US 24 or SH 91 or any freight railroad right of way.</td>
</tr>
</tbody>
</table>