Railroad Infrastructure Evaluation for
SS-24 ICBM Dismantlement Program in the
Republic of Ukraine

By:

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Abstract

The U. S. Defense Threat Reduction Agency (DTRA) was tasked under the Cooperative Threat Reduction Program to eliminate strategic offensive arms in Ukraine, which included the removal, transportation and dismantlement of SS-24 ICBMs. Transportation of the missiles was by rail and began in spring 2000. The missiles were transported 800 Km from Mikaylenki Arsenal to the dismantlement site at Pavlograd. The missiles’ nuclear warheads had been removed, but not the solid rocket fuel. There was concern that a derailment could cause the solid rocket fuel to ignite.

Prior to movement of the missiles, an existing conditions survey of the track structure was performed to determine the safety of the electrified rail line over which the missiles were to be transported. Based on existing conditions and operations on the line, repair recommendations were developed. The recommended repairs involved main line and yard track, embankments, bridge timber and special trackwork.

After DTRA evaluated the $5 million in recommended repairs, an independent analysis was conducted of 200 of the 800 Km of track to determine if the recommended repairs were necessary, and that operating alternatives were considered. The independent analysis evaluated a combination of infrastructure improvements and operating changes, which involved an on-track inspection, a review of operations and plans for the recommended repairs, and interviews with Odessa Railroad and Ukraine Ministry of Defense personnel. The independent analysis concluded that both infrastructure repairs and operating changes were necessary, and that there would be a savings in the estimated repair costs.
INTRODUCTION

The U.S. Defense Threat Reduction Agency (DTRA) was tasked under the Cooperative Threat Reduction Program with strategic offensive arms elimination in Ukraine. The program provided for, among other things, the removal and dismantlement of SS-24 Intercontinental Ballistic Missiles (ICBM) and dismantlement of the silos. The missiles were transported by rail from their storage facility at Mikaylenki Arsenal to the site of their dismantlement at Pavlograd, a distance of approximately 800 kilometers (km) (see Figure 1).

An initial survey for safety and stability of the 800 km of track was conducted in the winter of 1999 but did not include approximately 200 km of the Odessa Railroad between Miranovka and Alexandria. At the request of the Ukrainian government, that section was surveyed in the summer of 1999.

After the DTRA evaluated the scope of work developed by the Odessa Railroad and Bechtel National, Inc. (BNI), an inspection and independent analysis was commissioned to determine the existing conditions of and required repairs for the 200 km of track. The DTRA wanted to ensure that all repairs were necessary and that viable alternatives to safely transport the missiles had been explored. Therefore, the assessment included infrastructure improvements and operating suggestions to provide for the safe transportation of the missiles. Missiles to be transported had the nuclear warheads removed, but not the solid rocket fuel.

The project was approached in the following manner:

- Review of information and documents provided by the Odessa Railroad and BNI.
- Inspection of existing conditions and evaluation of proposed repairs over the 200 kilometers.
- Discussions regarding the repairs with the Odessa Railroad and Ukraine Ministry of Defense (MOD).

The track inspection was conducted utilizing an Odessa Railroad on-track inspection car, stopping at locations where repairs were requested. The requested repairs were divided into four categories:

- Areas where there are embankment stability problems.
- On open deck bridges where bridge timber is to be replaced.
- On sections of main line track where reconstruction is required.
- At turnouts and crossovers.

The track inspection was conducted in August 1999. Representatives of the Odessa Railroad, an Army major from the MOD and representatives of BNI accompanied us. The inspection was conducted from Znamenka in
a northerly direction to Korsun-Shevchenko and then from Korsun-Shevchenko in a southerly direction to the yard at Alexandria.

The inspection party got off the train at each location to inspect the track, embankment and bridge with respect to the recommended repairs. After inspection, a meeting was conducted with the Odessa Railroad and MOD representatives to discuss what was observed and how the assessment would progress.

**RAILROAD OPERATIONS**

**Existing Operations**

The Odessa Railroad operates freight and passenger service over the line on a two-track right-of-way. The 23 missile trains for this mission were proposed to operate on the southward track over the line with additional routing over other tracks in yards and station areas.

Operations over the line from May to September 1999 were comprised of 60 passenger and 80 freight trains daily. After September (and before May), the train density was reduced to 50 passenger and 80 freight. The terminus of the rail line is the seaport of Odessa. On a daily basis, there are 90 trains to be unloaded at 11 ports in the vicinity of Odessa.

Annual tonnage (metric) on the line is significant. The southward track experiences about 60 million gross tons (MGT) annually, while the northward track handles about 45 MGT plus empties. The loaded direction of the trains is southward towards Odessa.

The Odessa Railroad is not the only operator on the line. About 20 railroads from Ukraine, Russia, Belarus and other former Soviet republics operate on or interchange cars over the line. This increases the tonnage and accelerates wear on the rail and other track material (OTM), thus increasing maintenance and corresponding costs. In the United States, railroads that operate over another railroad’s lines commonly share maintenance costs, either directly or in a division of the revenues. This is not the case in Ukraine.

A timetable showing the speeds over this section was not obtained. According to the Odessa Railroad, typical speeds, whether freight or passenger, are approximately 60-80 kilometers per hour ([kph] [37-50 miles per hour-mph]). Through station areas and where track conditions warrant, the trains operate at restricted speeds, which were observed to be approximately 25 kph (15 mph). The railroad further reduces speeds in sharp curves and where
the rail is not continuously welded. Speeds in the vicinity of the identified problem embankments are 25 kph (15 mph) on the inside of the curves and 40 kph (25 mph) on the outside.

**Proposed Missile Train Operations**

According to the DTRA, the missile train movements were to occur over an 18-month period beginning in the spring of 2000, with approximately 23 trains (2 missiles on each) expected. The train sets were to be comprised of 2 missile carriers and support cars making a 10-car consist. The missile train consist, however, was not clearly made known. Based on railroad operating experience, the 10-car consist could be expected to be configured as follows: 2 locomotives, 1 idler/guard car, 1 support car, 1 missile car, 1 support/idler car, 1 missile car, 1 support car, 1 idler car and 1 caboose/guard car. The significance of this configuration is that the missile cars will not be on a bridge or bridge span, turnout, etc. at the same time. From an axle-loading standpoint, this is important. Based on the 18-month period, the trains will run about every 3½ weeks.

With respect to the tonnage hauled over the line and its impact on rail and track infrastructure wear, the track over which the 23rd train will run will have experienced approximately 90 MGTs more than that of the first train. The 90 MGTs represent approximately 15 percent of the life of the rail (based on a 600 MGT life of the rail) in tangent track and 30 percent of the life in curves. Therefore, approximately 15 and 30 percent of the life of the rail can be expected to go bad from the first to 23rd missile train, on tangent and curved track, respectively.

Initial recommendations for the safe and unimpeded movement of the missile trains are:

- No train should precede or follow the missile train for a distance of 50-100 kilometers (31-62 miles). MOD and Odessa Railroad will determine the actual distance based on the operating rules of the railroad and the characteristics of the signal system.
- The train should be operated at slow speeds.
- No trains should oppose the missile train on the opposite track.
- Operations through yards and stations areas should be at yard speed, approximately 15 kph (10 mph).
- Operations through stations and heavily populated areas should be at night or at off-peak hours.

**Rail Car Configuration**

The rail car configuration was determined based on photographs and sketches DTRA provided. The rail cars were not observed. They are 8 axle cars approximately 25 meters (81 feet) in length. The missile unit is approximately 17 meters (56 feet) in length. There are two truck pairs, one each at the front and rear of the cars.
For each pair of trucks, axle spacing is approximately 2 meters (7 feet) and truck spacing is 3.2 meters (10.5 feet). Axle loading, according to the Odessa Railroad, is 25 metric tons. The dimensions and capacity of the rail cars are shown in Figure 2.

PROPOSED REPAIR PROGRAM

General

The requested repairs are in four categories: track, embankment, switches and bridge timbers. The quantities and rough order of magnitude of the costs developed by BNI are presented in Table 1.

The proposed repairs are based on many factors, which are focused on operations and infrastructure. The repairs were identified as necessary to safely run the 23 missile trains between March/April 2000 and December 2001. The assessment of the repairs considered that normal maintenance would be performed on the line and particularly on the southward track.

Embankment Repair

Four areas on the Shevchenko-Ruygorod-Kamenka sections of the line have been determined to be unstable. The embankments range in height from 13.3 m (44 feet) to 21 m (69 feet). The total length of proposed embankment repair is approximately 1,850 m (6,070 feet). The proposed work is as follows:

- Km 217 and Km 225-226, Shevchenko-Ruygorod
- Km 233 and Km 234, Ruygorod-Kamenka

The proposed work consisted of embankment stabilization with sand, gravel and local drainage soil; extension and relocation of culverts; and power line and communication cable relocation. A sketch of the proposed repair (typical) is shown in Figure 3.

The proposed repairs were based on a design provided by ZAO Transporte (quasi-governmental engineering organization). The earthwork (shown in Figure 3) involved terracing the fill with a 1:1.8 slope. The design calls for placing local soils, sand and gravel. At the time of the inspection, work on the embankment problem at KmP 225-226 had started, but was halted due to lack of diesel fuel to operate the earth moving equipment.
Switch Replacement

The requested repairs were for the replacement of 31 No. 11 turnouts or crossovers with new, concrete switch timber packages. The proposal was to install new P-65 (65 Kg per meter =>143# per yard) No. 11 turnouts on concrete switch timber. The existing turnouts to be replaced are on wood switch timber. The replacement of switch timber only at crossovers 322/324 and 251/253 on the Znamenka section was also requested. The turnout replacement also includes the reconstruction of 1,162 m (3,812 feet) of the approaches to the turnouts.

Track Reconstruction

Complete reconstruction of the track was required at three locations:

- **Shevchenko Railroad Section #9** – reconstruction of 1,096 m (0.7 miles) of Track #5, which bypasses the platform and main line through Chernolesskaya station.
- **Znamenka Railroad Section #10** – reconstruction of approximately 4.8 km (3 miles) of southward main line between KmP 333 and 337.
- **Alexandria Railroad Section #11** – reconstruction of approximately 4.3 km (2.7 miles) of southward main line between KmP 339 and KmP 343

Bridge Timber Replacement

Complete replacement of the bridge timber was required at seven bridges with a total of 1,080 bridge timbers to be replaced. Except for the bridge at KmP 337, the replacement of the bridge timber is for the southward track only. At this bridge, the proposal is to replace the timbers on both the northward and southward tracks.

EXISTING CONDITIONS

General

The track structure is composed of rail, crossties, OTM (joint bars and bolts, tie plates and spikes or direct rail fixation, and rail anchors), and stone ballast. The condition of this material is dependent on age, use and operations. For the purpose of this assessment, the 60 MGTs on the southward track will be the operational condition considered.
In determining the condition of track, the life of the rail is typically the controlling factor. The life of rail is not measured in years, but by the tonnage over the line with a corresponding number of years based on a theoretical life of the rail. The life of the other track components is measured in relation to that of the corresponding rail.

The rail on the line is primarily 65 kilograms per meter (approximately 143# per yard). Its construction is either 25 meter (approximately 82 feet) jointed sections or 800 meter (approximately 2,625 feet) continuously welded sections of rail. The Odessa Railroad indicated that the life expectancy of the P-65 rail was approximately 550 to 600 MGTs on tangent track and 250 to 300 MGTs on curved track. Based on the 60 MGTs on the southward track, the rail on tangent track has a nine to ten-year life. On curved track, the life expectancy can be four to five years.

The Odessa Railroad ultrasonically tests the rail two to three times annually. This frequency should ensure that a rail failure would not occur without warning and that the rail is and will continue to be properly maintained.

Derailment information for the 200 km of railroad for 1998 and the first half of 1999 showed thirteen reported derailments in 1998 and three in 1999 through mid-June. The derailments appeared to be primarily due to wide gage and at turnouts. Other categories included rail end mismatches, low joints and broken rails. None of the derailments occurred at the embankment repair locations or at the bridges proposed for repair.

**Embankments**

The embankments proposed for repair have steep slopes that were identified as needing to be stabilized. They are predominantly in curves with the greater slope problems on the inside of the curves. Observations were made from the track and showed that the slope, although steep, maintained vegetation and there were no observable problems at the toe of slope. Some power poles tilted into the slope and the subgrade off the ballast section seemed to have settled. An embankment slope in the photograph in Figure 4 illustrates the problem.

None of the observations revealed operation-stopping conditions, which was evidenced by the continued operations of the line with minimal operating precautions (slow orders). Further, no remedial work had been performed nor was remedial work scheduled on the embankments, except for the embankment at KmP 225-226. At this location, the Odessa Railroad had extended the culvert and began to stabilize the slope on both sides. The work, however, was stopped by lack of fuel.


**Switches**

The turnouts were observed to be P-65 No. 11s on wood switch timber. They were inspected by their major components: switch points, frogs, switch timber and ballast, and operation. In general, the turnouts (including the two proposed for switch timber replacement only) proposed for replacement showed signs of wear, but the switch points appeared to be aligned, fit snugly against the stock rail and operated properly. Most switch points had some wear and some had been chipped. The frogs also showed signs of wear with some spalling and rail burns on the surface. The points of frog were mostly in fair to good condition with a few being worn or broken. The switch timber condition also appeared to be fair to good with approximately $\frac{1}{3}$ of the switch timber observed categorized as defective. The ballast condition was fouled in most instances with some areas in good condition. The fouled ballast was mainly in the station areas. A typical turnout proposed for replacement is shown in the photograph in Figure 5.

With respect to turnout maintenance, the Odessa Railroad admitted that they welded the points of frog and switch points as a corrective measure. They said, however, that they could only weld these turnout components once. (U.S. railroads, with proper welding rods and experienced welders, can weld frogs and switch points more than once.) Despite the assessed condition of the turnouts, the Odessa Railroad appeared to run over the turnouts with minimal operating restrictions (slow orders). The conditions observed did not seem to be atypical for a railroad with similar freight densities and tonnage.

It was observed that, of the 31 turnouts proposed for replacement, seven had already been replaced. It was asked that four turnouts at Zelonaya Station be added to the repair program to replace the seven that the railroad had completed.

**Track**

The track proposed for reconstruction was of standard construction with P-50 and P-65 jointed rail (25 m in length), wood crossties, spike or bolted fixation and rail anchoring. The track conditions on the main line between KmP 333 to KmP 337 and KmP 339 to KmP 343 were determined by observations from the track inspection car and on-the-ground sampling. Based on the on-the-ground sampling, it was observed that the rail was worn, but useable, there were enough good crossties to support and hold the rail, and the ballast was in fair to good condition. The photograph in Figure 6 shows the typical track condition found in these sections of the line.
Of the sections observed, there was an average of 22 bad out of 50 total crossties in the 25 m section of rail (crosstie spacing of 0.5 m => 20” spacing). (This equates to approximately 10 or 11 bad ties per 39’ length of rail [U.S. standard].) The number of crossties in a 39’ section of rail (industry standard ranges from 19” to 21”) is approximately 23. With an equivalent of 11 bad crossties per 39’ section of rail observed, there are approximately 12 good crossties. It was also observed that there was at least one good crosstie at each rail joint, and in most instances two.

According to the FRA Track Safety Standards, track with 12 good crossties per 39’ section of rail, are rated at FRA Class 4/5 in tangents and FRA Class 3 in curves greater than 2°. This means that, according to the FRA Track Safety Standards, the crosstie condition on the line allows for the speeds as shown in Table 2.

Since the FRA rates track at its lowest class determined by physical conditions, the sections of track inspected would be classified in the U.S. as FRA Class 3. This would allow maximum speeds of approximately 60 to 100 kph for freight and passenger trains, respectively. The observed speeds during the inspection trip appeared to be in line with these maximums. The highest observed speed was 85-90 kph on a tangent stretch of welded rail.

For the approximate 1.1 km of Track #5 at Chernolesskays Station, the track condition was fair to good. The rail showed some wear, but the track was not a main line track. It appeared to be a yard bypass track. The crosstie or ballast condition could not be observed because the ballast section was fouled and oil soaked. The crossties were presumed to be wood and the ballast, at one time, was stone. The photograph in Figure 7 shows the conditions observed on Track #5.

Bridge Timber

On-the-ground inspection of the seven structures found approximately half of the bridge timbers to be in fair to good condition. The bridge timber, except for some found on the bridge at KmP 143, was typical in size and milling for bridge applications. The photograph in Figure 8 shows a typical bridge timber condition observed.

At the bridge at KmP 143, spliced crossties were used because there were no bridge timbers available. At the bridge at KmP 346 a majority of the ties were in fair to poor conditions. At KmP 213, the tie condition was good. The spacing of the bridge timber was typical track construction. Guard rail and spanners or spacers were observed on the bridges and, where there was good timber, the rail appeared to be fastened properly.
Alternatives

General

Based on the inspection, review of information provided, and experience with respect to operating oversized and overweight loads, and hazardous material, the following assessment is provided. Operational and other infrastructure improvement alternatives to those requested by the Odessa Railroad and MOD exist. Each category identified as needing repair was addressed with respect to options, and their relative impact on safety and cost. The options will be focused on the immediate two-year horizon in which the missile trains are scheduled to run.

Regardless of which category of repair or alternative is selected, it is recommended that an inspection and repair crew precede the train to assess the track condition immediately before passage. The crew could make emergency repairs, or in the unlikely event of a serious problem, the approaching train could be stopped. Additionally, the MOD requires a track inspection 24 hours before the train.

Embankment Repair

The requested repairs involve the construction of terraced extensions of the embankments using sand and natural soils. The work also includes extending the cross culverts under the embankments. Because of the embankment stability problems, speeds have been reduced on the tracks.

There are several options:

- Do nothing and run at slow speeds on the southward track (approximately 15 kph).
- Do nothing and reverse run on the northward track at slow speeds (approximately 25 kph).
- Do nothing to the embankment, but install a slope measuring device and monitor the embankment during the 18-month period.
- Install soil nails or sheeting to temporarily stabilize the embankment during the 18-month period.
- Stabilize the embankment with stone rip-rap.

Regardless of the alternative, the Odessa Railroad must clean the cross culverts and maintain the ditches. This is evident in the geotechnical analysis provided where the storm and groundwater is retained in the silt and vegetation, further impacting the stability of the embankment.
**Turnout Replacement**

The alternatives to replacing the turnouts with new will require the operation of the missile trains through them at yard speed (approximately 15 kph). Since most of the switches are in yards and stations, the overall transit time for the missiles should not be impacted significantly. The alternatives are:

- Do nothing and run the trains over the turnouts at slow speeds.
- Repair the turnout steel (i.e., weld frogs, and repair and tighten switch points), re-ballast, where needed, replace only the switch timber that need to be replaced and line and surface.

**Track Reconstruction**

The 10 km of track proposed for reconstruction should be evaluated as to the desired and practical speeds of operation. For example, and for Track #5 at Chernolesskaya Station, alternatives to the 1.1 km proposed for reconstruction include re-routing the missile train onto other, newly constructed tracks that traverse the yard and station area. This in turn will eliminate the need to repair two switches. With respect to the track reconstruction, the alternatives include:

- Do nothing and run at slow speeds (25 to 40 kph)
- Replace the rail, crossties and OTM as needed. The tie condition of the 8.9 Km of main line track meets FRA Class 3 allowing speeds of approximately 65 kph.

The latter will require a detailed inspection of the track to determine replacement needs and material quantities.

**Bridge Timber**

Not all of the bridge timber needs to be replaced. The capacity of the bridge, however, should be certified to accommodate the axle loads of the missile trains. With respect to the replacement of the bridge timber, the alternatives are:

- Do nothing and operate over the bridges at slow speed.
- Replace a portion of the bridge timbers to hold the track and maintain gage.

Based on the inspection, the latter would require the replacement of approximately half of the timber on the bridges.
ALTERNATIVES ANALYSIS

This assessment will address both the infrastructure improvements and operating alternatives. The analysis is an “out of the box” assessment that does not accept “that’s the way it is” rationale, especially with respect to operations of the missile train. This assessment is based on the proposals submitted by the Odessa Railroad and MOD, observations made during the inspection trip, a review of the engineering documents provided, and railroad engineering, construction and maintenance principles.

The stability of the solid rocket fuel was identified as an important issue. According to BNI and DTRA, the solid rocket fuel in its transported state, is stable without a source of ignition and that there are no apparent sources of ignition along the railroad. It has been said that the LNG and flammable/chemical cars handled over this line are more unstable and more of a risk in comparison.

It should be recognized that this assessment is based on, among other things, the standards and guidelines of the FRA, American Railway Engineering and Maintenance-of-Way Association (AREMA) and U.S. railroad industry practice. These standards, guidelines and practices are accepted and adopted throughout the world. Certain physical characteristics may alter these standards, guidelines and practices, but not dramatically. In this case the difference between standard gage in the U.S. (1435 mm) and the Ukraine (1520 mm) is only 85 mm (3 3/8”). Hence, the physical laws that apply to railroad design and operations are not expected to differ greatly. Also, the construction methods and materials of the track structure are similar.

The assessment will consider the need to move the first missile train in March or April 2000. The evaluation of the different or repair proposals considered the ability to do the work under winter conditions. The focus is to ensure that the track structure is in satisfactory condition for the 23rd missile train to operate safely.

**Embankment Repair**

*Proposal*

The repair proposal for a terraced extension of the embankment using sand and natural soils appears to be too costly (approximately US$1.7 million). A report on the embankment at KmP 225-226 presents a plan to stabilize the embankment in the terraced slope fashion. The report’s presentation of the soils and geotechnical characteristics indicates that the terraced stabilization of the embankment with an approximate slope of 1.8:1 is required. The issues and problems to be encountered by this proposal are:
• The embankment would be extended out further than what would be needed if the embankment were stabilized with shot rock and stone.

• The proposed method could not be effectively worked during winter months.

• The relocation of communication lines and other facilities, and culvert extensions would add to the cost and duration.

The report, although recommending the reinforcement of the existing embankment, does not indicate the slope will fail catastrophically. The railroad has reduced speeds to 25 kph on the southward track (inside of curve) and 40 kph on the outside track. (It should be noted that this assessment is based on a review of engineering documents prepared in Ukrainian.) A critical embankment problem would stop all operations. The embankment would have to be repaired before operations are resumed.

Alternatives

• Do nothing and run at slow speeds on the southward track (approximately 15 kph).

  Operating at slow speeds reduces the dynamic loads transmitted to the subgrade, and thus the embankment on the inside of the curve. This alternative would allow the train crew to “walk the train” over the problem areas and observe signs of embankment failure in advance and stop the train to avoid an accident.

• Do nothing and reverse run on the northward track at slow speeds (approximately 25 kph).

  Like doing nothing and running at slow speeds on the southward track, this alternative would reduce the dynamic loading on the inside of the track and allow the train crew to “walk the train” over the problem area. It would distance the train from the inside of the curve, however, the condition of the outside embankment should be considered and handled accordingly.

• Do nothing to the embankment and install slope measuring devices, such as slope inclinometers and monitor the embankment during the 18-month period.

  This alternative proposes that the Odessa Railroad install devices, such as slope inclinometers and monitor the movement in the slope(s) both before and after the trains, and at predetermined intervals. This is so that the stability and/or movement of the embankment can be monitored, measured and addressed. The trains should also be operated at reduced speeds.
• Install soil nails or sheeting to temporarily stabilize the embankment during the 18-month period.

This alternative will provide for a temporary, but costly stabilizing of the embankments. It would allow for normal track speeds, but would require working during the fall and winter months, and frequent monitoring.

• Repair the embankment with stone.

By stabilizing the embankment with shot rock and stone, the work can be accomplished with less effort and equipment, and be done during winter months. With this type of stabilization, there will be minimal concern with frost, snow and ice, and spreading and grading the soils. The railroad has four quarries within 60-100 km (37-62 miles) of the four embankments. The stone could be hauled by rail car and dumped in place. This would stabilize the embankment slope from the toe, which is important to reduce the chance of a slip plane failure. The stone should be approximately 1 CY (or M³) at the toe and be reduced in size as the rock is dumped up the slope to subgrade elevation. A sample cross section that shows this approach to stabilizing the embankment is shown in Figure 9.

**Turnout Replacement**

**Proposal**

The Odessa Railroad’s proposal requires a major expenditure (approximately US$1.3 million) for turnouts. Although the turnout steel is somewhat worn, some of the switch timber is defective and the ballast fouled, the proposed replacement would require a significant expenditure with some work being performed during the winter.

**Alternatives**

• Do nothing and run the trains over the turnouts at slow speeds.

This alternative has the train crews “walk the train” over the turnouts at reduced speeds (15 kph). The slower speeds allow the wheels to “track” properly through the switch and frog and, if a derailment were to occur, the train would merely “sit down,” thus reducing the chance of the train tipping over. The reduced speeds should not have a significant effect on operations, as the majority of the turnouts are in yards and stations, and the trains currently operate at yard speeds. The Odessa Railroad should inspect the turnouts prior to each missile train. The railroad should also continue properly maintaining the turnouts. This alternative does not involve any repair or costs.
• Repair the turnout, re-ballast and replace defective switch timber.

Rather than replace the turnout, this alternative requires the Odessa Railroad to weld the switch points and frogs, replace the defective switch timber, re-ballast and line and surface through the turnouts. Like the “do nothing” alternative, the trains should operate at reduced speeds and “walked through” the turnout, and the turnout should be inspected prior to each missile train. The railroad should also continue to properly maintain the turnouts. This work can be accomplished prior to the winter of 1999-2000 and checked after the winter and before each train. The railroad should solicit assistance in welding to get more than one repair for the switch points and frogs. The cost of this alternative is less than that proposed by the Odessa Railroad.

Track Reconstruction

Proposal

The Odessa Railroad’s proposal to reconstruct 10 km of main line track is approximately US$1.9 million. The railroad’s proposal on the two segments would bring the track up the railroad’s standard of CWR on concrete crossties. The track reconstruction should be part of the railroad’s normalized maintenance program, based on the operations and tonnage over the line. The need to reconstruct is not because of the missile trains, but because of the number of trains and tonnage that routinely operates over the line. Track #5 in Chernolesskaya Station, which is designated as the missile train track, bypasses the yard and station platforms. It appears to be in poor condition, but can be bypassed by the missile train. Its repair would enhance the normal operations of the railroad.

Alternatives

• Do nothing and run at slow speeds (25-40 kph).

The two segments of main line track can be operated at slower than normal speeds to minimize the risk of derailment. (This is a common practice where there is a need to run trains with inadequate maintenance budgets.) The Odessa Railroad should maintain the track for its normal operations. This operating option, like the others, requires that a track inspection precede the missile train to look for track defects and repair them before the passage of a missile train. At Chernolesskaya Station, there are main line tracks that have been upgraded and could be used to run the missile trains at reduced speeds, such as 15 kph, which is typical in yards and stations.
• Replace the rail, crossties and OTM, as needed.

This option would replace the defective crossties, OTM and rail, and re-ballast the track where required. Track should be inspected to determine the defective ties, rail, and OTM. The rail should also be ultrasonically tested prior to the first missile train and every 3 or 4 months during the following 18 so internal defects in the rail can be detected and replaced before becoming a problem. The P-50 rail (50 kg/m => 110#/yd), although lighter than the P-65 section, should be adequate to accommodate the 25 metric ton axle loads. This option does not release the railroad from rehabilitating the approximate 9 kms as needed for current and future operations. This option would allow the missile train to operate at or near track speeds.

Because there are other tracks through Chernolesskaya Station, Track #5 can remain as an unimproved bypass track. However, and if required because of operating limitations through the station, the missile train could operate at yard speeds and be “walked through.”

**Bridge Timber**

*Proposal*

The Odessa Railroad’s proposal is for the complete replacement of the 1,080 bridge timbers on seven structures. Except for the bridge at KmP 337, the replacement is on the southward track. At this bridge, both tracks were proposed to have the bridge timber be replaced because there was no structure separating the tracks. By replacing the bridge timber on the northward track also, the Odessa Railroad wanted to reduce the chance of a derailment on the northward track affecting the southward track and missile train. The observations made during the track inspection revealed that approximately ½ of the bridge timber needed to be replaced. This included the standard crossties that were spliced together on the bridge at KmP 143. This option has an estimated cost of US$88,000 and would allow the track to be operated at normal speeds.

**Alternatives**

• Do nothing and operate over the bridges at slow speeds.

This option would require that maintenance be performed to allow the missile trains to operate over the bridges. The railroad would have to inspect and replace selected bridge timber (less than 50 percent). Because of the tie count (good vs. bad), the seven bridges can be operated at or approaching track speed.
speeds (according to the crosstie condition of the FRA Track Safety Standards). However and because of the nature of the train, it is suggested that it run at less than track speed.

- Replace a portion of bridge timber to hold the track and maintain gage.

This option calls for replacement of the defective bridge timber (approximately 50 percent). They should be replaced so that there are no more than two bad bridge timbers together and each joint is supported by two good bridge timbers. This includes all of the spliced crossties on the bridge at KmP 143, but not the bridge timber on the northward track on bridge 337. This option should, barring any structural problems with the bridges, allow for track speeds to be maintained.

RECOMMENDATIONS

The recommendations to move the missile trains are general in nature with respect to operations, and specific with respect to the proposed infrastructure improvements. The focus of these recommendations is to move the 23rd missile train as safely as the first. Major considerations in this analysis are the responsibilities of the Odessa Railroad to maintain its tracks to support current operations, stability of the solid rocket fuel being transported as part of the missile and operating requirements to move the train. The repairs should be those required to run the missile trains safely, where there are no operating alternatives or the tracks structure is such that the safety of the missile train is compromised. The repairs should not be made based on the normal operations over the 200 km of track.

Operational

The following are operating conditions that should be considered for the safe movement of the missile trains:

- The missile trains should be blocked (dispatched and train separation) to minimize the disruption to normal operations.
- The missile trains should be separated from trains ahead and behind by 50-100 km or whatever is considered reasonable and safe, based on signal system characteristics, train schedules and dispatching procedures.
- Trains on the northward track opposing the missile train should be minimized. Opposing direction trains should be held in yards or passing sidings where possible until passage of the missile trains. This would reduce the possibility of the northward train derailing into the path of an oncoming train.
- In addition to the 24-hour inspection proposed by the Odessa Railroad and MOD, the tracks should be inspected prior to each missile train and all defects repaired.
- Run a test train of equivalent length, weight and speed if conditions (i.e., weather) warrant or the track inspection 24 hours in advance of the missile train uncovers a problem.
- The missile train cars and equipment should be inspected before each operation.
- The Odessa Railroad should maintain and upgrade the line as required to support current and forecasted operations.
- The missile trains should be operated at slower than normal speeds to be determined by, among other things, track condition and geometry, and running through station areas.
- The railroad should give priority to the missile trains over regularly scheduled train movements.
- The railroad should consider dedicated power for a through movement to save on the time involved in crew and/or engine changes.

**Embarkment Repair**

To safely run the 23 missile trains, it is recommended that the embankment be stabilized with stone. This will provide a short-term fix with long-term benefits. This solution, common on U.S. railroads, has been known to last for considerable periods of time. Also, this alternative can be worked in the winter, which is essential to having the first missile train run in spring 2000. To implement this option, a basic design should be prepared.

**Turnout Replacement**

Although the 31 turnouts proposed for replacement have some worn steel and defective switch timber, and may need some re-ballasting, they should be able to be operated safely at slow speeds with minimal improvements such as replacing defective ties in kind, welding and adjusting the switch points, welding the frogs and installing ballast. The proposed concrete turnout packages, although a benefit to the normal operation of the Odessa Railroad, are not required if the Odessa Railroad maintains the turnouts properly. With respect to the two crossovers that are proposed to have new concrete crosstie packages, they should be improved in the same manner as that proposed for the 31 turnouts.
Track Reconstruction

The approximate 9 miles of main line track should be rehabilitated, rather than reconstructed. Defective wood crossties should be replaced, rail inspected and replaced as necessary and the track re-ballasted, lined and surfaced. The Odessa Railroad, however, should continue to maintain the tracks and program capital improvements that would rehabilitate the line to support normal operations. The rail should be ultrasonically tested periodically to find defects before they become a problem. Track #5 at Chernolesskaya Station should be neither reconstructed nor rehabilitated. The missile train should be run through the yard over the main line tracks that have been upgraded in the past.

Bridge Timber

Of the 1,080 bridge timbers proposed for replacement, only about half should be replaced. This includes the spliced crossties on the bridge at KmP 143. The 140 bridge timbers on the bridge at KmP 337 should not be replaced, as the proposal is a contingency or “what if” improvement and not necessary to run the missile train.

CONCLUSION

Details of the recommendations should be determined by a joint inspection with the Odessa Railroad and MOD. These recommendations and suggestions are based on the two-day inspection conducted in August 1999. A work plan should be developed to quantify the improvements recommended herein. Then, along with an operating plan that considers the operational improvements, the missile train movements can be formulated and scheduled.
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Figure 8: Typical bridge timber condition.

Figure 9: Typical section of embankment repair.
<table>
<thead>
<tr>
<th>Repair Category</th>
<th>Quantity</th>
<th>Estimated Cost</th>
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<tbody>
<tr>
<td>Embankment</td>
<td>3 Ea.</td>
<td>$1,658,000</td>
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<tr>
<td>Turnouts and Crossovers</td>
<td>33 Ea.</td>
<td>$1,268,000</td>
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<tr>
<td>Bridge Timber</td>
<td>1,080 Ea.</td>
<td>$88,000</td>
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<tr>
<td>Track Rehabilitation</td>
<td>10 km.</td>
<td>$1,859,000</td>
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<tr>
<td><strong>Total Estimated Cost</strong></td>
<td></td>
<td><strong>$4,873,000</strong></td>
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</tbody>
</table>

**TABLE 1.** Construction estimate for proposed repairs.
<table>
<thead>
<tr>
<th>FRA Class</th>
<th>Mi/Hr</th>
<th>Km/Hr</th>
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<tbody>
<tr>
<td>4/5 – Tangent</td>
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<td></td>
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<tr>
<td>Freight</td>
<td>60 – 80</td>
<td>96 – 128</td>
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<tr>
<td>Passenger</td>
<td>80 – 90</td>
<td>128 – 144</td>
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<tr>
<td>3 – Curves &gt; 2°</td>
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<td></td>
</tr>
<tr>
<td>Freight</td>
<td>40</td>
<td>64</td>
</tr>
<tr>
<td>Passenger</td>
<td>60</td>
<td>96</td>
</tr>
</tbody>
</table>

**TABLE 2.** Allowed speeds for crosstie conditions per *FRA Track Safety Standards.*
FIGURE 1. Locus map.
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