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Evaluation of the Federal Railroad Administration's Autonomous Track Geometry Measurement System Research and Development Program

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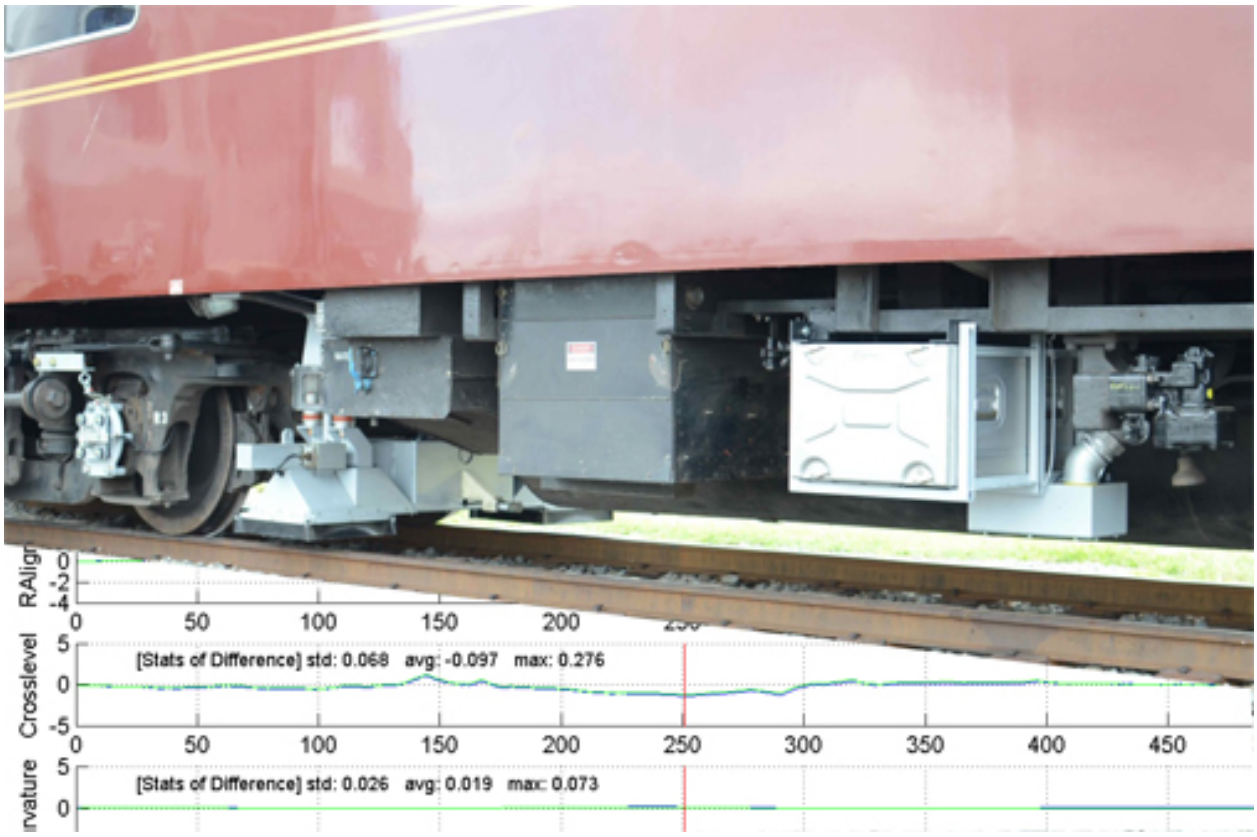

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This report evaluates the Autonomous Track Geometry Measurement System (ATGMS). It examines: 1) the extent of ATGMS usage, 2) what railroads think of ATGMS, 3) why ATGMS is not being employed more, 4) ATGMS performance indicators, 5) how to evaluate the impact of ATGMS, and 6) establishing research priorities to increase ATGMS adoption. Data was gathered by conducting structured interviews with organized labor, FRA's Office of Research Development & Technology, FRA's Office of Railroad Safety, ATGMS suppliers, Class 1 freight railroads, and passenger railroads. Railroads are interested in ATGMS but are not using it widely for the following reasons: 1) concern about when data requires track maintenance, 2) not enough specificity of location defects, and 3) data quality. FRA wants to use ATGMS to inspect more tracks at lower cost, have better data to set policy, and improve safety. Research priorities should be focused on: 1) data quality, 2) location accuracy, and 3) clear definition of when knowledge requires action. An evaluation plan is presented that supports needs for accountability and continuous improvement in the ATGMS R&D program. The plan places minimal burden on FRA personnel while tracking change over time.

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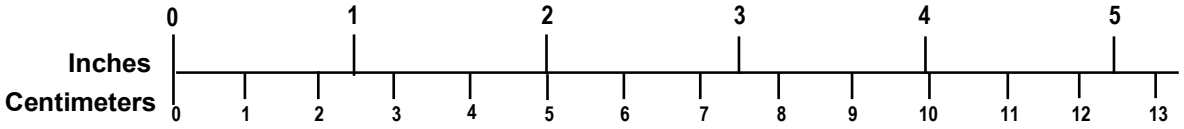

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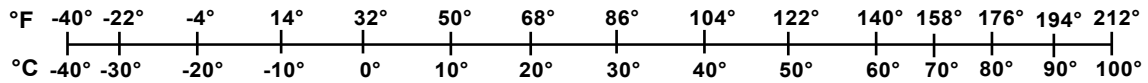

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Executive Summary

This report evaluates the Autonomous Track Geometry Measurement System (ATGMS)–a research and development (R&D) program sponsored by the Federal Railroad Administration (FRA), and managed by FRA's Office of Research, Development and Technology (RD&T). FRA performs research on track geometry because frequent measurement of track conditions provides knowledge of track change over time and leads to safer railroad operations.

ATGMS differs from present track inspection systems in three ways: First, it is autonomous, i.e. data can be collected and analyzed without human intervention. Second, the ATGMS equipment can be mounted on a variety of cars as they traverse track. Third, the system can transmit data to a central location for automated processing.

Current inspection requires humans in special cars to inspect and analyze data as they run over the tracks. Without the need for manned inspection vehicles, ATGMS could inspect a great deal of track at a lower cost. More inspection would provide richer data both for the railroads and for FRA's Office of Railroad Safety (RRS), and help prevent track-geometry related accidents.

FRA is aware that ATGMS has not been fully embraced by the railroad industry, but beyond this realization, we are missing answers to key questions such as: Where is ATGMS being used? What do railroads think of the technology? Why is ATGMS not being employed to a greater extent? What indicators can FRA use to track movement toward greater use? How can the cost-effectiveness of ATGMS be evaluated? How might RD&T's research agenda be constructed to increase the rate at which ATGMS is adopted? The purpose of this report is to address these questions.

The methodology used in this report involved structured interviews with individuals from organizations closely involved with ATGMS and who are personally involved with ATGMS efforts being conducted at their organizations. They were representatives from the following groups: 1) organized labor, 2) RD&T, 3) RRS, 4) ATGMS suppliers, 5) Class 1 freight railroads and 6) passenger railroads. Because of limited resources and restrictions imposed by the Paperwork Reduction Act, only a limited number of non-government respondents were included in this report. The limited sample may have led to an incomplete view of how railroads are using ATGMS. However, we believe this report's conclusions involving barriers to use and indicators of success do apply across the industry, especially for larger railroads. Since no small railroads were included in the analysis, this report's relevance to short line and regional railroads is unknown.

At present, railroads are interested in ATGMS because the system may allow more track to be inspected at a reasonable cost without allocating special track time and equipment for inspections, and the resulting data can be used to do more effective maintenance. However, this interest has not translated into widespread use. At the moment, the most optimistic view is that some testing is going on and interest level remains high. Why has ATGMS not penetrated further into routine operations? One critical reason is that there is no firm definition that specifies when a railroad "knows" that there is a problem requiring maintenance in the data stream. Without a clear delineation, concerns about regulation and liability will limit commitment to wider use of ATGMS. Two other ATGMS issues are serious impediments to widespread adoption–not

enough accuracy when specifying defect locations, and problems with data reliability (i.e. false positives).

FRA is also interested in using ATGMS technology in its Automated Track Inspection Program (ATIP). Like the railroads, FRA is interested in inspecting more track at lower cost, while implementing more effective policies with respect to inspection and providing greater levels of safety. Because ATGMS has consequences for railroad maintenance procedures, which in turn have consequences for safety, FRA's interest in this technology interconnects with that of railroads. Industry has a desire for research on data quality and location accuracy, and for better definition of when data about track becomes "knowledge" about track. The distinction between "data" and knowledge" is important because "knowledge" has regulatory and liability implications.

The report details models that both identify critical factors that affect the implementation of ATGMS and the types of outcomes that can be expected. Performance indicators are identified based on those models. Evaluations based on these indicators must support FRA's need for accountability and to document achievement, and continuous improvement. Also, evaluation procedures must place a minimal burden on FRA personnel and track change over time.

1 Introduction

The demands placed on railroad tracks can be substantial. Stresses generated by train traffic and by weather (principally changes in temperature) can degrade track quality and cause derailments. To help minimize derailments and improve safety, the Federal Railroad Administration (FRA) Office of Research, Development and Technology (RD&T) has been conducting a variety of research and development (R&D) projects to detect potential problems in rail. One of those research programs is the Autonomous Track Geometry Measurement System (ATGMS).

Figure 1: Consequences of Derailment

Autonomous is the key term because measurements taken on moving cars can be transmitted to a central location where data can be analyzed via a set of processing algorithms to determine track conditions. Combining remote processing with automated decisionmaking is a major break with present track geometry measurement systems, which require a dedicated crew with special expertise and technology to transverse the track as they scan it for problems. ATGMS offers the possibility of unattended measurement and decisionmaking, which would greatly increase the frequency of inspections, the number of miles inspected, and knowledge of track conditions as they change over time.

While to what extent a human can be (or should be) removed from technical decision-making is a matter of debate, ATGMS is based on a vision of greater automated information processing and decisionmaking, which will lead to more track inspection. More inspection also holds out the possibility of railroads being able to better predict track integrity problems, and thus minimize both maintenance costs and disruption of revenue service.

1.1 ATGMS Evaluation

As part of RD&T's efforts to continually improve its activities and programs, the office commissioned this report to evaluate its ATGMS program. The evaluation consisted of two phases. Phase One was a literature review. Phase Two was a set of interviews conducted with individualsrepresenting points of view of key stakeholders in government and industry. Five groups were represented:

- Labor
- FRA's RD&T
- ATGMS vendors
- FRA's Office of Railroad Safety (RRS)

- Railroads (passenger and freight)

The evaluation covered three topics:

- Implementation. To what extent is the ATGMS technology being implemented? If so, how?[1]
- Indicators of success. To what extent is the ATGMS technology meeting its vision, goals, and objectives? What indicators can currently measure its success? What has changed? In future evaluations, what new measures of success can be added as the system is more fully deployed?
- Sustainability. What opportunities could be leveraged to enhance this initiative and, if it is successful, maintain its long-term sustainability?

1.1.1 Perspectives of Multiple Stakeholders

RD&T decided to perform this evaluation of ATGMS so it could make decisions that would lead to a system that was technically capable, financially viable, and acceptable to potential users of the technology. To obtain this knowledge, experts and professionals with a range of relevant perspectives were interviewed:

- Labor
- Railroads
- ATGMS vendors
- RD&T (project managers and technical personnel)
- RRS personnel involved with FRA's Automated Track Inspection Program (ATIP)

[1] The original Statement of Work (SOW) included: "What are the indicators of success?" in this category, but this question was redundant due to the entire "success" category, and is thus omitted here.

2 Methodology

2.1 Collaborative Development

Before this evaluation could proceed, two fundamental actions were taken:

- The Statement of Work's questions were transformed into specific interview questions that would elicit useful information from respondents
- The evaluation's respondents were selected.

Both the evaluation team and FRA personnel collaborated on these tasks, and they developed a methodology with FRA expertise that is structured to be maximally useful for those who wish to use the findings in setting R&D policy.

2.2 Sampling

The collaborative team selected the respondent group shown in Table 1. There are two limitations inherent in the selection process. First, the number of respondents had to be limited due to restrictions imposed by the Paperwork Reduction Acts, so only five of the seven Class 1 freight railroads were included in the sample. This decision could introduce bias into the findings, but based on our analysis of the data and our knowledge of the railroad industry in general, we believe that information on the reasons for use (e.g. cost, functionality) are accurate though the information on the extent of use (e.g. number of units deployed), may be distorted.

Second, no small railroads were included in this group. Thus we have no data on how ATGMS could be used to good advantage by the large number of railroads in this country that have far fewer resources (money, people, technical expertise) than the major carriers.

Table 1: # Respondents by Category of Stakeholders

Group	# respondents
Railroad	6 [a]
FRA – ORD [b, c]	3
FRA – OS [c]	2
Suppliers	3
Labor	1

a- These represent two separate types of respondents. Five Class 1 freight, and passenger
b- One of these respondents was a DOT employee who is well connected to ATGMS, but not an FRA employee
c- These respondents are federal employees.

2.3 Developing Questions that Addressed FRA's Information Needs

Developing specific questions from the general questions found in the Statement of Work allowed people to discover and clarify exactly what information they wanted to know, and the exercise generated a set of questions that elicited useful information during an interview. There were specific interview questions developed for FRA personnel (Appendix A), 2) labor (Appendix B), 3) ATGMS vendors (Appendix C), and 4) railroads (Appendix D).

Because respondents were promised anonymity, their names are not revealed in this report. However, all FRA personnel who had input into nominating respondents agreed that the sample was comprised of appropriate people from each of their organizations.

2.4 Interview Process

Potential respondents were contacted by email and/or phone and the project was explained to them. All of the people who were contacted agreed to be interviewed. In two cases, the respondent identified another representative of his or her organization that would be more appropriate for an interview. In all cases, every company contacted and all of the government employees agreed to participate. All the railroads were Class 1 freight carriers or major passenger carriers. The labor representative was well positioned to appreciate labor's perspective on ATGMS technology.

Prior to each interview, the respondent was sent a list of the questions. Fifteen interviews were conducted. Respondents were promised anonymity and assured that any information conveyed in the report would be phrased in a manner that would not lead the reader back to any one person or any one company. The respondents were sent a copy of the notes after each interview and asked to check for accuracy and to add any information that might be relevant. (These files were encrypted.) Interview data were content analyzed with an eye toward discovering important areas of agreement and disagreement among the groups of respondents. Finally, the respondents would also have an opportunity to review a draft of the report.

2.5 Analysis and Data Presentation

The objective of this exercise was to find points of agreement about ATGMS across different points of view and identify critical differences that could influence FRA's approach to forming its R&D agenda.

However, presenting this type of information in a way that preserves respondents' anonymity is difficult. The solution was to paraphrase responses in a way that is true to the intent of the respondent, and then it was edited to remove the possibility of identifying the source of the information.

3 Use of ATGMS

This section examines how the ATGMS technology is being used by the railroad industry and FRA.

3.1.1 ATGMS Use in the Railroad Industry

At present, all railroads inspect their track geometry because they are required to by FRA regulations and they have found that derailments are costly and disruptive. However, it is uncertain if they are using *autonomous* systems for doing their inspections. This evaluation reveals that they know of ATGMS technology and are considering its value, but with respect to actual use, the railroads are performing some testing with ATGMS but are not using it routinely

Table 2 provides a sense of the railroads' engagement with ATGMS.

Table 2: Railroads' Interest and Use of ATGMS

RR	Illustrative Paraphrase of Extent of Use
1	▪ We are using it to improve our internal operations ▪ Our interest is high. We have a strong desire to work with it. ▪ We have ATGMS and are practicing how to deploy it. ▪ We are working with a supplier to make it work for our context
2	▪ We are analyzing the need for more units of ATGMS ▪ We have been using it for a few years.
3	▪ Not actively using it but keeping an eye on it. ▪ Have done some field testing ▪ Talking with vendor about doing some further testing
4	▪ Comparison tests in 2014 ▪ Independent testing in 2015 ▪ We have been working with the technology for a while
5	▪ We are/were willing to use it. ▪ We worked with it and planned to test it, but didn't
6	▪ We are very familiar with the technology. ▪ Will do the testing next year ▪ In the process of obtaining two units to test ▪ We tested one, but without the autonomous part.

The responses in Table 2 make it clear that all of the respondents are taking ATGMS seriously, but that except for railroad 2, routine use is limited to testing. The conclusion about railroads' interest is supported by responses from representatives of three suppliers of ATGMS, who confirmed the sentiment of the railroad respondents (i.e. that there is considerable interest, but little large scale deployment). These responses are noteworthy not just because they confirm the railroads' responses, but because as suppliers to the industry, they have a broad view of the entire

industry. Railroad respondents were asked about their own companies, while suppliers were asked about their view of the entire industry.

3.1.2 FRA Use of ATGMS

For more than thirty years the FRA has run the Automated Track Inspection Program (ATIP)[2]. In 2011, ATIP began to evaluate ATGMS and between July 2013 and June 2014, approximately 41,000 miles of ATIP inspection took place using ATGMS.[3] From the point of view of detection and data transmission to a central location, ATGMS is allowing ATIP to fulfill its obligations with respect to inspection. ATGMS automatically identifies locations at which measured track geometry exceeds class-based thresholds as identified in the Track Safety Standards. For quality control purposes, experts review the cases.

[2] http://www.fra.dot.gov/Page/P0633

[3] Saadat, S., Stuart, C., Carr, G., and Payne, J. (2014) *Development and Use of FRA Autonomous Track Geometry Measurement System Technology* American Railway Engineering and Maintenance of Way Association, September 28 - October 1, Chicago IL.

4 Value of ATGMS

In the previous section, it became evident that routine use of ATGMS is minimal but interest in the technology is high. All the respondents were asked a question that would allow them to address advantages and disadvantages of the technology[4]. Five of the six railroad respondents volunteered possible advantages. Both respondents from the ORS also provided information with respect to the railroads, as did one of the three ORD personnel.

All respondents who discussed advantages gave responses that can be categorized as: "more inspection, less cost"[5]. Moving beyond the simple ratio of miles of track per dollar, three respondents discussed the value of increased inspection frequency to generate additional track condition trend data and assist with planned maintenance. This is important because their responses illustrate a common theme (i.e. the impact of new technology). The future of ATGMS may be like other technological innovations, which begin with a desire to "do more of what we always did, but better and faster", and then they evolve into novel uses that were impossible without the new technology.

A useful way to think about the two advantages of ATGMS (mile/dollar and improved track condition monitoring) is shown in Figure 2 . In Scenario 1, ATGMS only results in more track inspection at lower cost. In Scenario 2, ATGMS is deployed in such a manner that it both decreases inspection cost, and increases the quality of track maintenance. Scenario 2 shows the complete range of possible advantages of using ATGMS. However, given the factors that govern organizational change, it should not be assumed that tactics conducive to effecting scenario 1 will necessarily also bring about scenario 2.

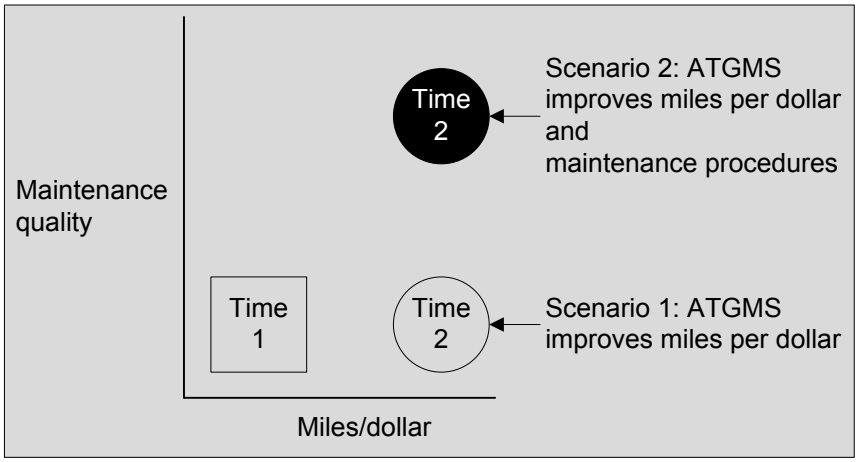

Figure 2: Value of ATGMS over Time

If the value of ATGMS is so well acknowledged, what explains the minimal level of adoption that was described in 3.1.1? The next section attempts to answer this question.

[4] Vague non-substantive responses such as "ability to inspect track" were omitted from the analysis. There were very few such responses.

[5] The sample was too small to detect differences among types of respondents, e.g. suppliers and railroads.

5 Impediments to Implementation of ATGMS

Several elements of the interview were used to determine why the use of ATGMS is not more widespread. First, respondents were asked a question about the advantages and disadvantages of ATGMS. Second, respondents were asked to identify the important and barriers to adopting ATGMS. Finally, many respondents volunteered relevant information as they answered other questions. We consolidated the responses and grouped them into categories.[6] Table 3 presents the number of responses in each category, along with a few typical illustrative paraphrases to convey a sense of what people said.

Table 3: Impediments to Implementation of ATGMS

Response Category[7]	# respondents	Illustrative paraphrases
Point in the data stream that marks obligation to act begin	10	▪ A major disadvantage is that the FRA does not specify the obligation of the railroads with respect to "prior knowledge". ▪ What are the remediation requirements with respect to the FRA and litigation?
Precise location of the defect that was detected	7	▪ Distinguishing between tracks may be a problem unless GPS precision improves ▪ Location determination – there is the multi-track problem
Data quality and analysis	7	▪ Quality of data not assured. On a manned car data can be validated in real time. ▪ There is a problem with false alarms (false positives)
Equipment reliability, maintenance, management, cost	4	▪ The problem is maintaining equipment once deployed in revenue service cannot be overstated. ▪ Who will watch over it? Is it sitting in a shop or on a siding?
Work process that flows from data	4	▪ Procedures for handling the data are not established. For instance, how to get data to track supervisor?
Power to equipment in operation	3	▪ Challenge of running an unmanned car with power issues can be large.
Data transmission reliability	3	▪ Communication relies on cell towers. That means dead periods, maybe no data for 100 miles.
Security of data transmission	1	▪ A lot of sensitive information is going over the Internet

A major barrier to using ATGMS is that there is no definition that determines when a railroad is obligated to take action if a track exceeds FRA Track Safety Standards. Does the railroad need to take action when data is first recorded within gigabytes of data? Do they act when the data are analyzed and a flaw detected? Or do they act when a human being takes note that the problem

[6] As with the data on "advantages", vague non-substantive responses were omitted from the analysis. There were very few such responses.

[7] "Cost benefit" was also mentioned once, but is omitted in this figure because the "cost/benefit" objective is inherent in the reasons why railroads are interested in ATGMS.

exists? The answer matters because there are serious regulatory and liability consequences involved, and at present, the FRA has not provided clear guidelines on this matter. In fact, respondents' contextual narrative around this topic shows it to be even more important than might be assumed from its top rating in Table 3. That narrative often included modifying statements of the form: "This is the most critical problem".

Another issue stems from strong sentiments among the survey participants that location data is not precise enough to direct maintenance actions. For instance, there will never be any ambiguity in a manned car as to where a track problem is, because there are people who can manually inspect the track and know where to direct the maintenance crew. That is the level of precision that railroads want, and they do not believe that ATGMS can provide it. (Of course there is always the question of whether such precision is needed in order for the net benefits of ATGMS to exceed the present status of track inspection. But it is certainly true that the respondents in this evaluation believe that more precision is needed.)

Also, the respondents strongly suggested that the quality of the data is not good enough to drive action. They are concerned with false positives and the consequences of asking people (and the organization as a whole) to act when it is not necessary. As one respondent put it: "How many times can you ask people to get up in the middle of the night?"

However, according to the data presented in section 4, it is clear that respondents see considerable value in ATGMS. There are legitimate concerns about using it, but it is the case that if those concerns were addressed, the technology would be embraced.

Finally, the data in this section should be interpreted with caution. The methodology asked respondents for recall, not for recognition. For instance, they were asked questions such as "What do you think the advantages of ATGMS are?" but they were not given a list of ten possible advantages and asked to rate them in terms of importance.[8] If the list-based approach had been taken, it is possible that lower rated issues might have been rated as more important. For example, it is easy to imagine that confronted with a list of possible barriers, many respondents would have looked at the item "power to equipment" and rated it reasonably high. Still, all the respondents had deep experience with ATGMS in the railroad industry, and the data does reflect their answers.

[8] It is true that the interviewer version of the protocol contained probes that could be used to help people elaborate on or expand their responses. But using probes at the discretion of the interviewer (as is standard practice) does not constitute a systematic presentation of a full list of possibilities.

6 Indicators of Railroads' Deployment of ATGMS

Based on the data presented above, it is possible to develop performance indicators that will reflect the extent to which ATGMS is being implemented, why a particular degree of implementation has been achieved, and what impact that implementation is having. For such indicators to be used successfully, it is necessary to: 1) embed the indicators in a causal model, and 2) provide an explanation of how the behavior of the model will lead to a particular status for ATGMS.

6.1 A Logic Model of ATGMS Impact on Industry

The data above (desirable use of ATGMS (Figure 2) and barriers to ATGMS implementation (Table 3)), can be combined into a logic model to explain how ATGMS might be implemented successfully, and if successful, what impact that implementation may have. That model is presented in Figure 3.

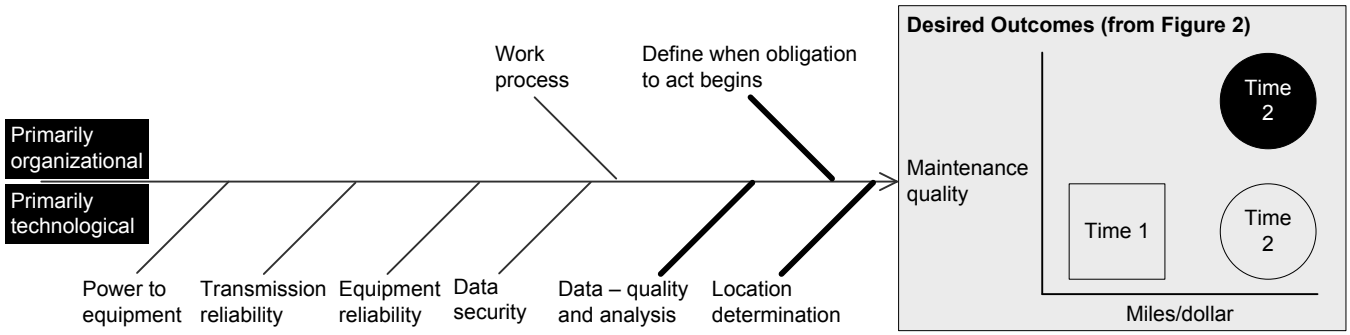

Figure 3: Barriers to Implementation

The scenario depicted in Figure 3 shows:

- A successful outcome where, over time, railroads use ATGMS both to increase the number of miles inspected (and presumably the frequency of inspection), and do better maintenance, (for example, planning track upgrades based on analysis of trends in track degradation over time).
- In order to achieve widespread use of ATGMS, progress must be made in overcoming the problems identified in Table 3.
- Factors that explain implementation are both: 1) organizational (top of main arrow), and 2) technological (bottom of main arrow.)
- Some of the elements in Table 3 are more important than others. (The important ones are indicated by thick lines.)

To guide evaluation, performance metrics can be identified for each element of Figure 3.

6.2 Performance Metrics

Table 4 identifies an initial set of candidate performance indicators that could measure the implementation of ATGMS and its impact on the railroad industry.

Table 4: Candidate Performance Indicators for Impact on Industry

Element in Model	Performance Indicator
Outcome of ATGMS Use	
Miles/dollar inspected	▪ # of miles inspected ▪ $ for inspection ▪ Net $ for inspection (accounting for all operational costs ▪ Change in above pre-post implementation of ATGMS
Maintenance procedures	▪ Frequency of inspections ▪ Decision criteria as to when, where to inspect ▪ Decision criteria for maintenance priorities
Implementation: Organizational	
Work process	▪ Appearance of informal, accepted procedures for acting on data ▪ Appearance of formal procedures for acting on data
Definition of "obligation to act"	▪ FRA/industry deliberation activity to define terms ▪ Formal definition of terms
Implementation: Technical	
Power to equipment	▪ R&D activity to support ATGMS power technology ▪ Supplier support for adoption of R&D power technology ▪ Adoption of power technology
Transmission reliability	▪ R&D on technical solutions ▪ # of miles of dead zones ▪ Hours trains spend in dead zones
Equipment reliability	▪ Equipment down time ▪ Maintenance cost ▪ Procedures for managing equipment
Data security	▪ # hacking incidents ▪ Amount, nature of data obtained
Data quality/analysis	▪ # of false positives / negatives ▪ $ cost of false positives ▪ Hours expended on false positives
Location determination	▪ # of cases track anomaly not in location indicated by ATGMS ▪ Hours expended finding correct location ▪ # times correct location not determined

6.3 Using the Model to Evaluate ATGMS

The visual form of Figure 3 (arrow-shaped and moving from left to right) implies that the ATGMS implementation and outcome can be explained with an additive methodology -- count up the indicators for each element, combine them, (weighted perhaps for the more important factors), and reach a determination. This approach is useful and should be done, but it would be prudent to use another approach as well.

That other approach is to consider a single, "global" indicator that reflects the overall amount of change in the barriers to implementation that are depicted in Figure 3, as opposed to looking only at particular amounts of change in particular elements. Including a global indicator will catch an important aspect of how technology adoption actually happens, while exclusive reliance on an additive approach will not. Individual railroads will place different priorities on various implementation factors. Each railroad will differ in its tolerance for "less than perfection" on any one factor. Railroads will differ in their technical and organizational capabilities to deal with particular implementation barriers.

Not every railroad will have the same incentive to improve its track maintenance capabilities to the same degree. Because of these differences it is likely that different configurations of a *reasonable amount of change*, in a *reasonable number of inputs*, could result in the same degree of progress in different railroads. Therefore it would be worthwhile to include a view of "success" as the amount of change in the causal model as a whole, rather than only as a sum of change in each individual element. Because this assessment would require qualitative expert judgment, it cannot be substituted for the mathematical approach presented in the previous paragraph. It should however, be included as a parallel methodology when evaluation is conducted.

These indicators above apply to the deployment of ATGMS and the impact that deployment may have on the railroad industry. A second set of outcomes deals with FRA operations.

7 Indicators of Success for FRA Operations and its Interaction with Industry

Two questions for FRA employees touched on the manner in which ATGMS might affect the organization:

- How ATGMS might affect the FRA's internal operations?
- How ATGMS might affect relations between FRA and industry?

This section deals with responses to both of those questions as a single inquiry. Responses tended to be thin and few. Across the five respondents and two questions, only nine short answers (some of which were redundant) emerged. Still, and at the risk of reading too much into sparse data, it does seem as if ATGMS has the potential to induce important changes in how FRA operates.

- The FRA will have better data on specific portions of track, which will facilitate improved analyses of where track maintenance is needed. This new knowledge can affect how the FRA deploys its personnel and the demands it makes on the railroads.
- The FRA will have an overall understanding of the condition of track. This is a type of knowledge that is not currently available.
- The FRA and the railroads will have knowledge of track degradation over time that is currently unavailable.
- Because of the above, the FRA will become more efficient and effective in how it deploys its inspectors. More importantly, these changes in knowledge about track may induce change in FRA's policy and in the demands it makes upon the railroads. What those changes may be, however, and what consequences they may have, is not known at present.

These data lead to a second "logic model" (Figure 4) that can be used to evaluate the impact of ATGMS on both the industry and FRA. (Figure 3 was the first.)

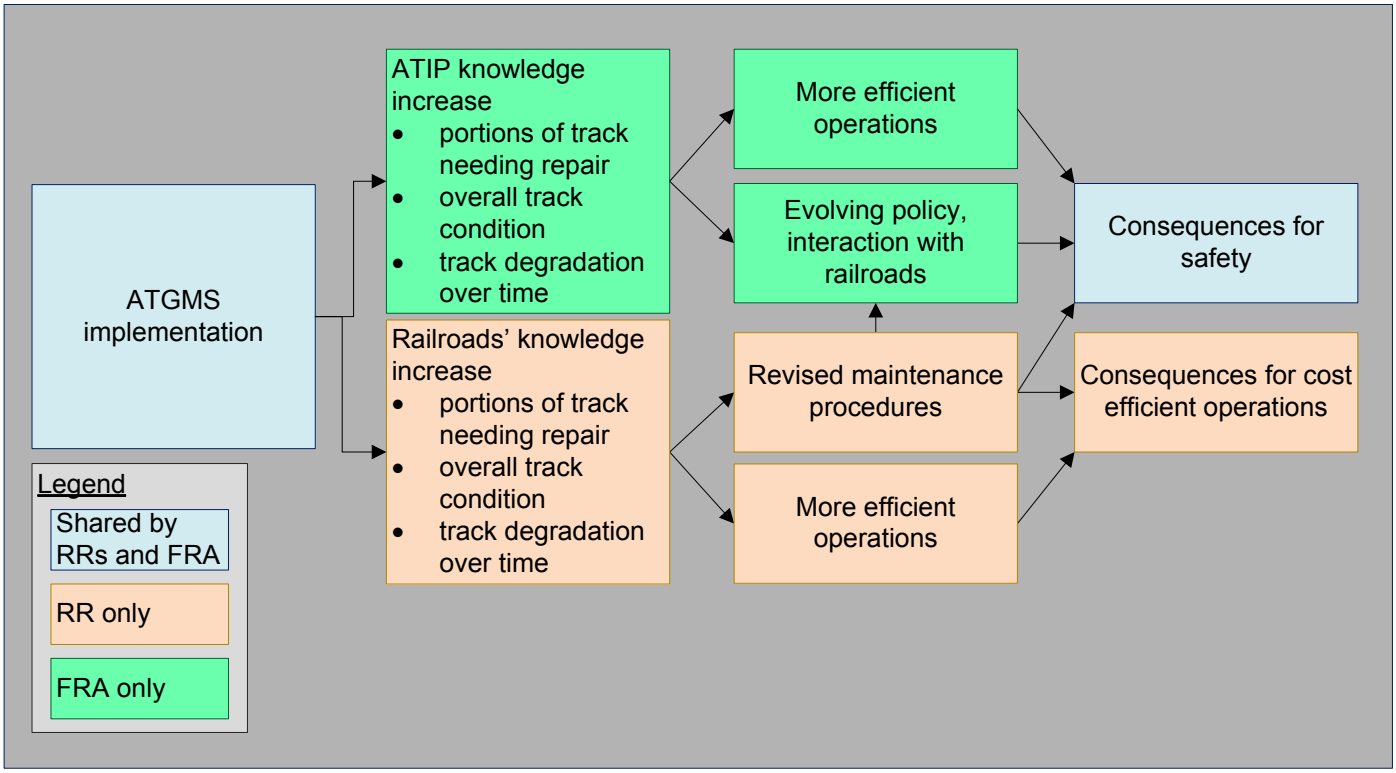

Figure 4: Indicators of Success: FRA Operations and Interaction with Industry

As **Figure 4** indicates, there are two "swim lanes" that travel from ATGMS implementation to long term success.

Railroad Implementation of ATGMS

Here, railroads adopt ATGMS for their own internal purposes, and not for any reason related to inspection or reporting relationships imposed by the FRA. Along this path, railroads use ATGMS to get more and better data about track conditions, and use the data to improve their maintenance procedures. That improved maintenance, in turn, leads to both improved safety and more cost efficient operations. Here, the focus is on how implementation and knowledge about track condition leads to improved safety and efficiency.

FRA Use of ATGMS

Here, ATGMS is embedded in ATIP. The immediate consequences are similar to that experienced by the railroads. In a change that is analogous to what the railroads may experience, FRA will both increase its efficiency (miles inspected per dollar), and also gain greater understanding of track conditions. The consequence of that newfound understanding may be changes in FRA's policies, thus leading to increased safety. However, in this model there is an additional way in which policy may be affected. As the railroads change their maintenance procedures, the FRA may consider those changes as events that will affect its policies.

Thus as with the path for the railroads, the "FRA" path in Figure 4 identifies both long term and intermediate success measures. Long term, success is indicated by improved safety. There are two interim measures:

- Operational efficiency.
- Evidence of policy evolving based on better knowledge of track, and also on attention to maintenance procedure changes within the railroads.

8 Next Steps

The data reported above have implications for two sets of actions that ORD should take:

- ORD's research agenda.
- An evaluation process to support ORD's ability to meet stakeholders needs in industry and in the rest of the FRA, and also to demonstrate accountability to other parts of the government.

8.1 ORD Research Agenda

All respondents were asked to offer recommendations to ORD with respect to R&D priorities. Twenty five suggestions were offered (Table 5).

Table 5: Recommendations for R&D

Recommendation	# of Nominations	Illustrative Paraphrase
Data – (e.g. quality, validation, interpretation)	9	▪ We cannot afford to have too many false alarms as this technology spreads across platforms
Location accuracy	4	▪ Distinguishing between tracks may be a problem unless GPS improves
Expanded range of measures	3	▪ We need technology to measure conditions that ATGMS does not currently measure ▪ Switch point measurement ▪ Direct measurement of track strength
Beginning of "knowledge of defect"	2	▪ Convene Class 1s to deal with regulations concerning defect data
All others	1 each (7 total)	▪ Non-contact tachometer ▪ Test with Class 1 railroad ▪ Ability to mount on different platforms ▪ Training on equipment installation and repair ▪ Develop automated systems to see if equipment is working properly ▪ Identify best ways to operate – special car, or put in revenue service ▪ Validate technologies that a variety of vendors bring to market

High priority items for ORD action can be drawn from Table 5 (which reflects technical needs), and from Table 3 (which identifies impediments to the use of ATGMS). Considering the findings in those tables, two priorities emerge.

- Better data quality.

- Assistance with establishing a clear definition of when data about track condition becomes "knowledge" about track condition.

These two priorities are closely followed by a third:

- Improved location accuracy.

We know that ORD is already considering projects that speak to these R&D priorities. (Examples include an ATGMS pilot as well as plans for increased usage of ATGMS with "Remote Desk" for ATIP.) We recommend that the findings reported above (Table 5) be considered when these, and similar plans, are developed.

8.2 Evaluation for Accountability and to Support ATGMS R&D

This report has identified models and associated performance indicators that can: 1) assess what is needed to further the implementation of ATGMS and 2) determine the impact that ATGMS can have for the railroad industry and for the FRA (Figure 3, Table 4, and Figure 4).

ORD would benefit from implementing an evaluation process that would provide accountability and a record of achievement and help ORD to continually improve its ATGMS program. This process should consist of three elements.

Brief, regular interviews:

Key people would be interviewed via phone or email on a regular basis. Depending on the people and their roles, interview frequency would be monthly, quarterly, semi-annually, or annually. The purpose of the interview would be to obtain information about the impact of the project, significant events, and reasons that explained what happened. The length of the interviews would vary between 15 and 30 minutes. Time limits could be strictly observed because the intent of the interviews would *not* to obtain in-depth information. Rather, the intent would be to collect relevant information at a frequency that allowed change over time to be observed.

Typology of projects:

The evaluation would assess the impact of activity that is designed to meet a specific objective, (e.g. improving the location accuracy of ATGMS detection). Such activity may involve only one single project. In practice, however, pursuing a technical goal will probably involve multiple funding awards. Evaluation would focus on overall impact and not on the project management of any given contract or task order. To maintain the appropriate focus, a typology would need to be maintained that shows the relationships among multiple R&D efforts.

Index to key documents:

In order for the evaluation to succeed, it must have reliable access to relevant documents (e.g. reports, presentations, articles, project plans, and timelines. It is likely that the needed information already resides in accessible archives. To minimize duplication, we recommend that to the greatest degree possible, document access should employ an index to existing locations rather than serving as a central repository.

9 Conclusion

This evaluation examined to what extent railroads were using ATGMS and what FRA could do to further the use of this technology. At present, railroads are interested in the technology because of its potential to allow more track to be inspected within reasonable cost, and to use that data to do more effective maintenance. That interest, however, has not translated into widespread use. The best that can be said is that some testing is going on, and that interest remains high. The question remains as to why ATGMS has not penetrated further into routine operations.

One critical reason is that railroads are concerned about not having firm definition (does the author mean "well-defined information on") of when in the data stream they can know with certainty that there is a problem requiring maintenance. Without such a clear delineation, concerns about regulation and liability will arise and thus limit commitment to wider scale use of ATGMS. Two other issues are also serious impediments to use: Not enough specificity as to exactly where a defect is, and limited data quality i.e. false positives).

FRA is interested in using ATGMS technology in its ATIP. FRA's reasons are similar to those of railroads–more track inspected at lower cost, more effective policy with respect to inspection, and greater levels of safety. FRA's interests in ATGMS are linked to railroads' interests since railroads' changing maintenance procedures may in turn affect FRA's policy {when it comes to track inspection? – check with author}.

[Future?] Evaluation of the ATGMS program needs to provide outcome data to document achievement and to guide continuous process improvement. As such, the data collection burden needs to be minimal, while data collection itself must be frequent enough to detect trends and accomplishments.

Appendix A Interview Protocol for FRA Personnel

Autonomous Track Geometry Measurement System (ATGMS) Technology: A Program Evaluation Initiative by the FRA's Office of Research and Development

The FRA's Office of Research and Development (ORD) is conducting a pilot program to address core evaluation questions to improve the effectiveness and impacts of its research and development (R&D) priorities for the Railroad industry.

This interview is about one of those R&D activities – autonomous track geometry measurement systems (ATGMS). With ATGMS, track is inspected from revenue service trains by means of unattended instrumentation, with minimal direct human involvement.

FRA has contracted with the Fulcrum Corporation to conduct and independent evaluation of the use of ATGMS technology. Fulcrum will keep your responses confidential, and only report summary findings.

The interview will last about 30 – 45 minutes, and will take place on --- *insert day, date, and time* ---. We will call you at --- *insert phone number*---. Below are the major questions we will be asking. There is no need for you to write out responses, we will take notes. Afterward we will send you a copy of our notes for your review and comment.

If you have questions about the interview, contact --- *insert name, contact info for primary interviewer* --. Thank you in advance for your support in providing the information necessary for successful program evaluation with respect to ATGMS technology.

Work History

1) What is your job title?
2) What are your duties at the FRA?

ATGMS

3) Please give us a brief overview of your familiarity with ATGMS.
4) From your point of view as an FRA employee, how might ATGMS technology affect FRA – Industry relationships?
5) From your point of view as an FRA employee, how might ATGMS technology affect the FRA's internal operations?
6) From what you have seen, do you have a sense of what options railroads are favoring with respect to ATGMS? Do nothing, test, deploy, consider some other kinds of technology?
7) From what you have seen, do you have a sense of what advantages and disadvantages railroads see with ATGMS? Please consider anything that may be relevant.
8) Do you know any railroads who tested ATGMS but decided not to deploy the technology? What were their reasons?
9) Do you know any railroads who are currently testing ATGMS technology? If so, what are they doing with it?
10) Considering everything you have told us, what do you see as the major barriers and facilitators to railroads' using ATGMS technology?
11) Considering everything you have told us, what are the major challenges for the FRA if ATGMS technology proliferates in the industry?
12) What should ORD's position be with respect to ATGMS? For instance, are there particular projects they should be pursuing? Should they be involved at all with ATGMS?

13) How many railroads that you know of are currently using ATGMS in routine operations?

14) Is there anything else you think we need to know that we have not already covered?

Appendix B Interview Protocol for Labor

R&D for Autonomous Track Geometry Measurement System (ATGMS) Technology:
A Program Evaluation by the FRA Office of Research and Development

FRA Office of Research and Development (ORD) is conducting a pilot program to address core evaluation questions to improve the effectiveness and impacts of its research and development (R&D) priorities for the Railroad industry.

This interview is about one of those R&D activities – autonomous track geometry measurement systems (ATGMS). With ATGMS, track is inspected from revenue service trains by means of unattended instrumentation, with minimal direct human involvement.

FRA has contracted with the Fulcrum Corporation to conduct and independent evaluation of the use of ATGMS technology. Fulcrum will keep your responses confidential and only report summary findings.

The interview will last about 30 – 45 minutes, and will take place on --- *insert day, date, and time* ---. We will call you at --- *insert phone number*---. Below are the major questions we will be asking. There is no need for you to write out responses, we will take notes. Afterward we will send you a copy of our notes for your review and comment.

If you have questions about the interview, contact --- *insert name, contact info for primary interviewer* --. Thank you in advance for your support in providing the information necessary for successful program evaluation with respect to ATGMS technology.

Work History

1) What is your position in the labor union?

What does ATGMS mean to you?

2) Please give us a brief overview of your familiarity with ATGMS.

3) From your point of view as someone in organized labor, what do you believe are the advantages and/ disadvantages in deploying ATGMS technology?

4) What improvements do you believe are desirable to make ATGMS more beneficial to railroad employees? Are there ways it could work differently that would better serve employee needs?

5) From what you know, what options are railroads favoring with respect to ATGMS: Do nothing, test, deploy, consider some other kinds of technology; other?

6) Considering everything you have told us, what are the most critical barriers and facilitators to using of ATGMS technology?

7) Assume that FRA could fund research to address any of the issues we discussed above. What would you like to see FRA do? Is there a role for FRA at this time relating to ATGMS? What is it?

8) Is there anything else you think we need to know that we have not already covered?

Appendix C Interview Protocol for ATGMS Vendors

Autonomous Track Geometry Measurement System (ATGMS) Technology: A Program Evaluation by the FRA's Office of Research and Development

The FRA's Office of Research and Development (ORD) is conducting a pilot program to address core evaluation questions to improve the effectiveness and impacts of its research and development (R&D) priorities for the Railroad industry.

This interview is about one of those R&D activities – autonomous track geometry measurement systems (ATGMS). With ATGMS, track is inspected from revenue service trains by means of unattended instrumentation, with minimal direct human involvement.

FRA has contracted with the Fulcrum Corporation to conduct and independent evaluation of the use of ATGMS technology. Fulcrum will keep your responses confidential, and only report summary findings.

The interview will last about 30 – 45 minutes, and will take place on --- *insert day, date, and time* ---. We will call you at --- *insert phone number*---. Below are the major questions we will be asking. There is no need for you to write out responses, we will take notes. Afterward we will send you a copy of our notes for your review and comment.

If you have questions about the interview, contact --- *insert name, contact info for primary interviewer* --. Thank you in advance for your support in providing the information necessary for successful program evaluation with respect to ATGMS technology.

Work History

2) What is your job title?

2) What have your roles been as an equipment supplier to the railroad industry over the last few years?

ATGMS

3) Please give us a brief overview of your familiarity with ATGMS.

4) What ATGMS equipment have you been offering to the railroad industry?

5) What options are railroads favoring with respect to ATGMS? Do nothing, test, deploy, consider some other kinds of technology?

6) When you talk to railroads, what are they telling you about the advantages and disadvantages of ATGMS? Please consider anything that may be relevant.

7) Do you know any railroads who tested ATGMS but decided not to deploy the technology? What were their reasons?

8) Do you know any railroads who are currently testing ATGMS technology? If so, what are they doing with it?

9) Considering everything you have told us, what are the major l barriers and facilitators to railroads' using ATGMS technology?

10) What should ORD's position be with respect to ATGMS? For instance, are there particular projects they should be pursuing? Should they be involved at all with ATGMS?

11) How many railroads that you know of are currently using ATGMS in routine operations?

12) Is there anything else you think we need to know that we have not already covered?

Appendix D Interview Protocol for Railroads

Autonomous Track Geometry Measurement System (ATGMS) Technology: A Program Evaluation by the FRA's Office of Research and Development

The FRA's Office of Research and Development (ORD) is conducting a pilot program to address core evaluation questions to improve the effectiveness and impacts of its research and development (R&D) priorities for the Railroad industry.

This interview is about one of those R&D activities – autonomous track geometry measurement systems (ATGMS). With ATGMS, track is inspected from revenue service trains by means of unattended instrumentation, with minimal direct human involvement.

FRA has contracted with the Fulcrum Corporation to conduct and independent evaluation of the use of ATGMS technology. Fulcrum will keep your responses confidential, and only report summary findings.

The interview will last about 30 - 45 minutes, and will take place on --- *insert day, date, and time* ---. We will call you at --- *insert phone number*---. Below are the major questions we will be asking. There is no need for you to write out responses, we will take notes. Afterward we will send you a copy of our notes for your review and comment.

If you have questions about the interview, contact --- *insert name, contact info for primary interviewer* --. Thank you in advance for your support in providing the information necessary for successful program evaluation with respect to ATGMS technology.

Work History

1) What is your job title?

2) What have your roles been in the railroad industry over the last few years?

Use of ATGMS

3) Please give us a brief overview of your personal familiarity with ATGMS.

4) What is your company's experience with ATGMS? (Tell us about anything from preliminary small scale planning, to field tests and implementation.)

5) What is your company's basic inclination at the moment with respect to ATGMS? For instance are there plans to consider its use, test it, or scale it up in the company?

6) What do you see as advantages and disadvantages in using ATGMS in your company? Please be expansive in your response and consider anything that may be relevant.

7) Considering everything you have told us, what are the most critical barriers and facilitators to further use of ATGMS technology?

8) What should ORD's position be with respect to ATGMS? For instance, are there particular projects they should be pursuing? Should they be involved at all with ATGMS?

9) Is there anything else you think we need to know that we have not already covered?

Abbreviations and Acronyms

ATGMS	Autonomous Track geometry System
ATIP	Automated Track Inspection Program
FRA	Federal Railroad Administration
ORD	Office of Research and Development
OS	Office of Safety
R&D	Research and Development

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