



## **9<sup>TH</sup> QUARTERLY REPORT - PUBLIC**

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# **Validating Non-Destructive Tools for Surface to Bulk Correlations of Yield Strength, Toughness, and Chemistry**

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### **Prepared For**

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# PROJECT OBJECTIVES AND REPORT SUMMARY

## Project Objectives

The deliverables of this project will facilitate the use of non-destructive surface testing: micro-indentation, micro-machining, in situ chemistry, and replicate microscopy analysis as accurate, efficient, and cost-effective tools for material property confirmation.

This work will provide benefits to pipeline safety, energy continuity, and integrity assessment programs since the developed techniques and models and validated testing technology will not require a line to be taken out of service or destructively cut out samples from the in-service pipeline.

The results of this project will also be applicable to pending DOT/PHMSA regulations that require operators to backfill their material property records for grandfathered pipeline segments and/or those that do not have adequate material records.

## Report Summary

During the ninth project quarter the following items were completed (see the **Technical Status** section for greater detail):

### Task 3 - Develop and Execute Testing Matrix

#### Laboratory (Bulk) Testing of 70 Pipe Samples

- Completed. 100% of all lab testing is done.

#### NDE Toughness Testing of 30 Pipe Samples

- All NDE tests are done except 30 NDE toughness tests on pipe coupon samples. These fracture toughness values should be provided by the end of November 2020. This will keep the final task of modeling on track for the surface to bulk modeling, as well as the draft final report for the project.

#### Data Collection and Initial Trend Analysis

- Completed the Milestone M15 - Summary of executed testing plan data input into project database (Excel Flat Table) and delivered it to DOT via upload to the DOT MIS project site.

### Task 4 - Data Analysis and Model Development and Optimization

- Continued causal-based modeling using non-linear ordinary least squares (OLS) regression with single and multiple microstructure forms. Expanded the use of categorical and non-linear continuous relations based on metallurgical principles.

- Extend the validation and demonstration with the newly provided data sets for both yield strength and ultimate strength.
- Finalized linear model, quadratic model, Gaussian process model, and Bayesian network model and associated R codes with full 70 samples dataset.

### **Task 6 - Project Management**

- Submitted Milestone **M15** - Summary of executed testing plan data input into project database (Excel Flat Table) on 10/31/2020.
- Submitted Milestone **M16** - 9<sup>th</sup> Quarter status report on 10/31/2020.
- Submitted Milestone **M23** - Conducted 2020 Peer Review #2 of Project (Virtual). Presented on 10/21/2020 and uploaded to the DOT MIS project site.

### **Risks**

- All project tasks are on schedule after aggressive efforts by GTI and ASU to keep these on track. There are no budget or scope issues.

# BUSINESS AND MILESTONE STATUS

## (Project Quarter #9: 8/1/2020 to 10/31/2020)

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### Tasks Scheduled in this Reporting Period

Table 1 shows the project tasks performed in this reporting period. Task 2 was completed last quarter. All tasks are on schedule.

**Table 1: Lists of Tasks in this Reporting Period**

Task	Scheduled Start	Scheduled Completion	Completion Status
<b>Task 3</b> - Develop and Execute Testing Matrix	5/1/2019 <sup>(1)</sup>	10/31/2020	<b>Completed</b>
<b>Task 4</b> - Data Analysis and Model Development and Optimization	8/1/2019 <sup>(1)</sup>	1/31/2021	<b>Ongoing</b>
<b>Task 6</b> - Project Management	8/1/2018	4/30/2021	<b>Ongoing</b>

<sup>(1)</sup> GTI started Tasks 3 early to allow early coordination with NDE subcontractors and service providers; ASU and GTI started work in Task 4 early to develop a framework for model experimentation and testing of model performance with the calibration data set provided early by GTI.

### Milestones for Activities/Deliverables Completed

Table 2 shows the project milestones for activities/deliverables/tasks **completed** in this reporting period. All Milestones/Deliverables are on schedule.

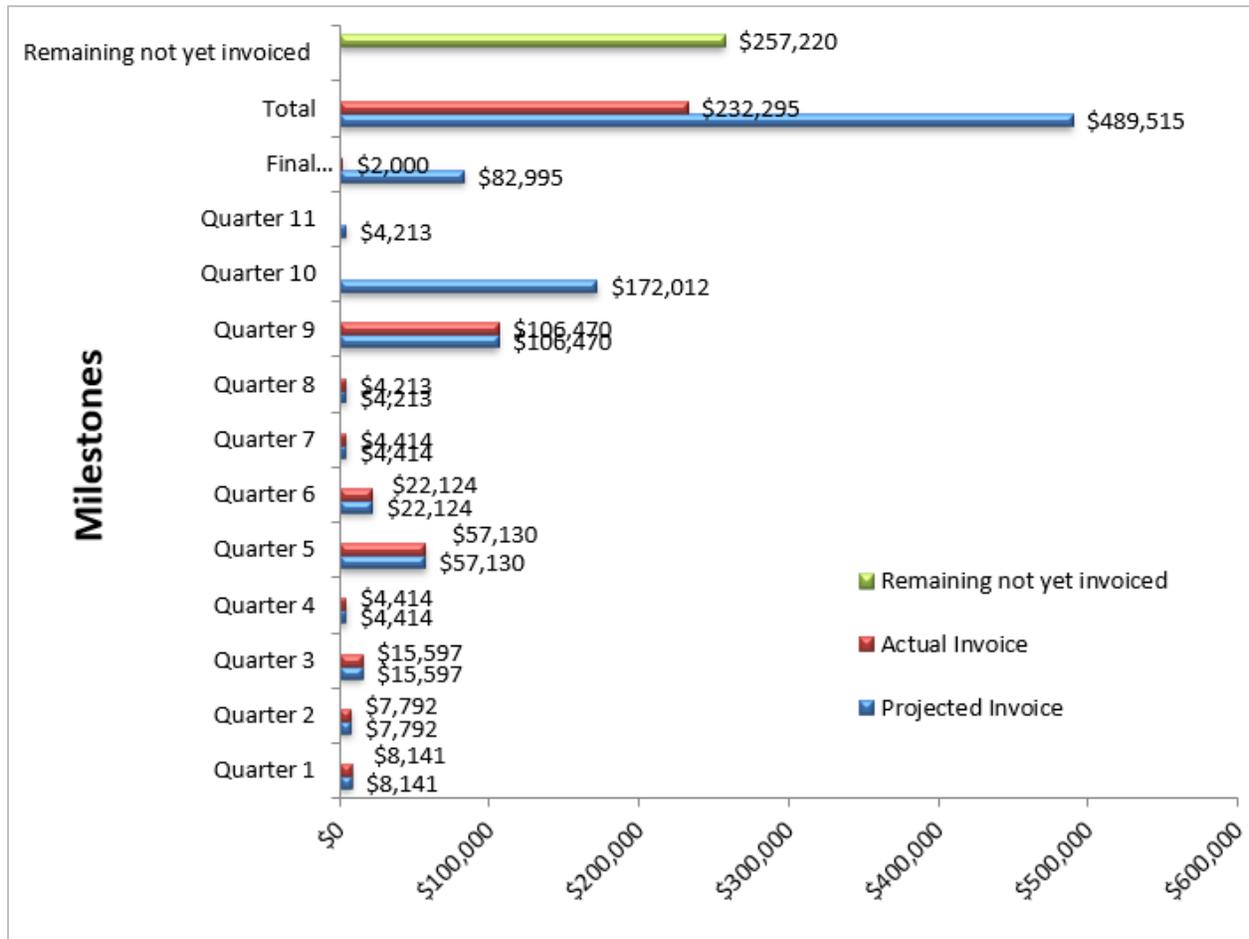
**Table 2: Lists of Milestones Linked to Activities/Deliverables/Tasks this Reporting Period**

Item No.	Task No.	Activity/Deliverable	Quarter No.	Scheduled Due Date	Completion Date	Payable Milestone/Title
15	3	Develop Testing Matrix and Execute Testing	9	10/31/2020	10/31/2020	Summary of Data Analysis and Model Generation and Optimization submitted
16	6	9 <sup>th</sup> Quarterly Status Report	9	8/1/2020	10/31/2020	Submit 9 <sup>th</sup> quarterly report
23	6	Peer Review #2 - Virtually Administered	9	10/21/2020	10/21/2020	Prepare presentation and present. Submit presentation file.

## Resource Status

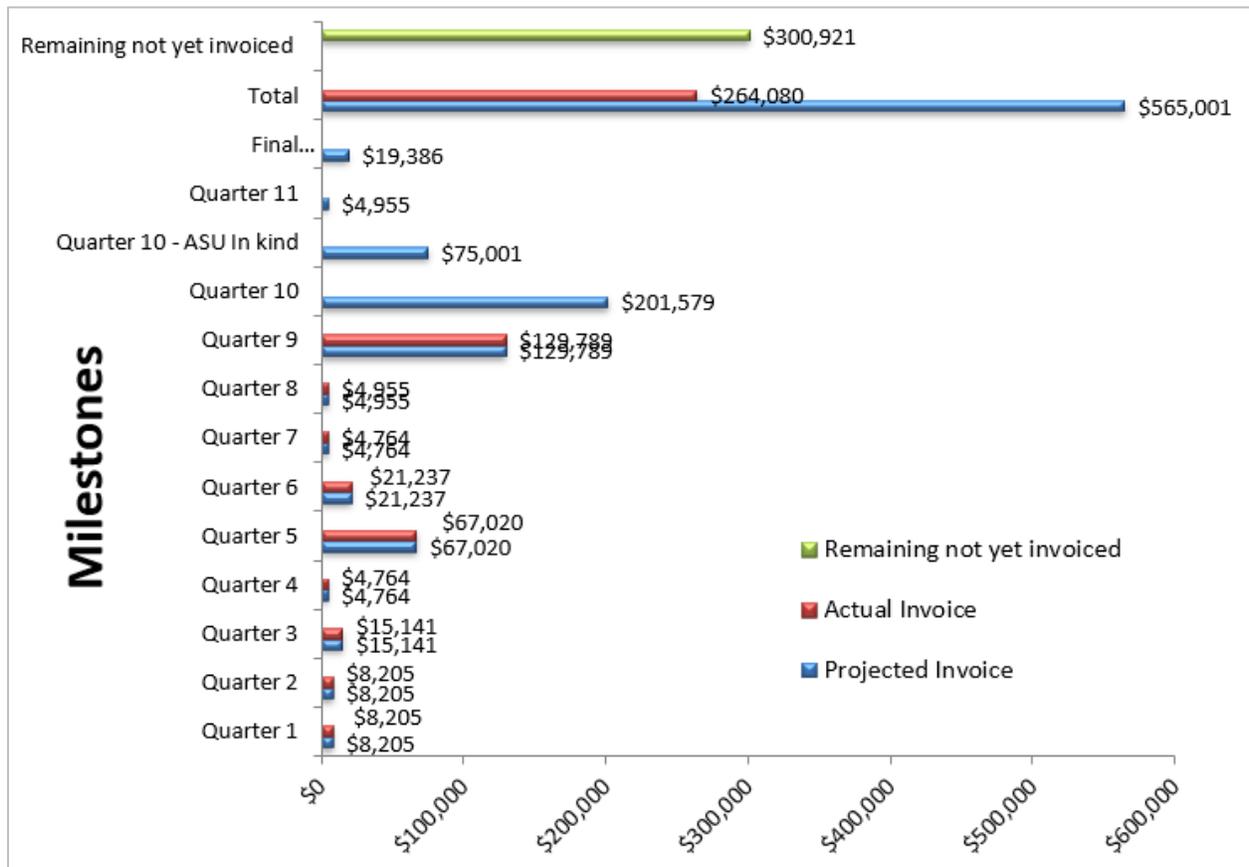
The nature of the contract for this research effort is fixed price, with clearly defined milestone/deliverable payments. Please see Figure 1 for an update on the fund status for DOT/PHMSA, and Figure 2 for the fund status of OTD and ASU.

**Figure 1: Quarterly Payable Milestones/Invoices – DOT PHMSA**



The 9<sup>th</sup> quarter invoice will be issued shortly after the end of the 9<sup>th</sup> project quarter.

**Figure 2: Quarterly Payable Milestones/Invoices – OTD and ASU**



The 9<sup>th</sup> quarter invoice will be issued shortly after the end of the 9<sup>th</sup> project quarter.

## Project Risks

- All project tasks are on schedule after aggressive efforts by GTI and ASU to keep these on track. There are no budget or scope issues.

# Schedule Update

The updated project schedule is shown in Figure 3.

Figure 3: Project Schedule

ID	Month	Task / Milestone Name	Start	Finish	% Complete	2018		2019				2020				2021	
						Q1	Q2	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1	---	<b>Task 1 - Form Technical Advisory Panel and Scope Confirmation</b>	8/1/2018	1/31/2019	100%												
2	1	M1 - Conduct kick-team meeting and present scope of work and objectives	10/31/2018	10/31/2018	100%												
3	3	M2 - Submit final TAP list and finalize tasks and methods	10/31/2018	10/31/2018	100%												
4	6	M4 - Confirmation of subcontract SOW in place	1/31/2019	1/31/2019	100%												
5	---	<b>Task 2 - Develop Project Database and Pipeline Sample Library</b>	11/1/2018	1/31/2020	100%												
6	9	M6 - Develop a project database on existing data	4/30/2019	4/30/2019	100%												
7	18	M11 - Submit summary of pipeline sample library	1/31/2020	1/31/2020	100%												
8	---	<b>Task 3 - Develop &amp; Execute Test Matrix</b>	5/1/2019	10/31/2020	95%												
9	15	M9 - Submit project testing/plan matrix	10/31/2019	10/31/2019	100%												
10	27	M15 - Submit summary of executed testing plan data input into project database	10/31/2020	10/31/2020	100%												
11	---	<b>Task 4 - Data Analysis and Model Development and Optimization</b>	8/1/2019	1/31/2021	30%												
12	30	M17 - Summary of data analysis and model generation and optimization submitted	1/31/2021	1/31/2021	0%												
13	---	<b>Task 5 - Final Report and Implementation Guide</b>	10/31/2020	4/30/2021	0%												
14	33	M25 - Prepare and submit final draft report	4/30/2021	4/30/2021	0%												
15	NA	M26 - Address comments and submit final report	4/30/2021	4/30/2021	0%												
16	---	<b>Task 6 - Project Management</b>	8/1/2018	4/30/2021	75%												
17	3	M3 - Submit quarterly report - Q1	10/31/2018	10/31/2018	100%												
18	6	M5 - Submit quarterly report - Q2	1/31/2019	1/31/2019	100%												
19	9	M7 - Submit quarterly report - Q3	4/30/2019	4/30/2019	100%												
20	12	M8 - Submit quarterly report - Q4	7/31/2019	7/31/2019	100%												
21	15	M10 - Submit quarterly report - Q5	10/31/2019	10/31/2019	100%												
22	18	M12 - Submit quarterly report - Q6	1/31/2020	1/31/2020	100%												
23	21	M13 - Submit quarterly report - Q7	4/30/2020	4/30/2020	100%												
24	24	M14 - Submit quarterly report - Q8	7/31/2020	7/31/2020	100%												
25	27	M16 - Submit quarterly report - Q9	10/31/2020	10/31/2020	100%												
26	30	M18 - Submit quarterly report - Q10	1/31/2021	1/31/2021	0%												
27	33	M19 - Submit quarterly report - Q11	4/30/2021	4/30/2021	0%												
28	NA	M20 - Present at public event or publish a paper	4/30/2021	4/30/2021	0%												
29	NA	M21 - Final virtual meeting	4/30/2021	4/30/2021	0%												
30	NA	M22 - Peer review #1 (date TBD)	5/1/2019	5/1/2019	100%												
31	NA	M23 - Peer review #2 (date TBD)	5/1/2020	10/21/2020	100%												
32	NA	M24 - Peer review #3 (date TBD)	1/1/2021	1/1/2021	0%												

# TECHNICAL STATUS

## (Project Quarter #9: 8/1/2020 to 10/31/2020)

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This section provides a high-level overview of the technical activities during the reporting quarter and the status.

Additional details, reports, presentations and other support material are placed in this report's Appendix and referenced below.

### Task 3 - Develop and Execute Testing Matrix

#### Laboratory (Bulk) Testing of 70 Pipe Samples

1. Completed the remaining plots of the three Charpy measures and identified a small number of pipe samples that need additional (higher temperature) Charpy tests to definitively determine the upper shelf location and associated toughness values. These extra Charpy tests were scheduled and completed during the quarter and include the development of the S-curves for absorbed impact energy, lateral expansion, and %-shear failure surface.
2. With the Charpy testing complete, now 100% of all lab testing is done. Only 30 NDE toughness tests remain, and are discussed in the NDE section below.

#### NDE Toughness Testing of 30 Pipe Samples

1. MMT informed GTI that they will not be able to conduct the NDTT NDE toughness testing and provide the surface-based toughness values before the end of 2020 - the drop dead date to get the results for analysis and make the project end date.
2. GTI retrieved the 30 pipe samples back from MMT and arranged for another NDE technology company, Frontics, to test the samples and provide fracture toughness data from the surface measurements.
3. These 30 NDE toughness values will be compared to the bulk toughness values from the Charpy testing, and used for further surface to bulk modeling.
4. Frontics took custody of the 30 pipe coupon samples in October, and is tentatively scheduled to provide GTI the NDE results of fracture toughness by the end of November 2020. This will keep the final task of modeling on track for the surface to bulk modeling, as well as the draft final report for the project.

#### Data Collection and Initial Trend Analysis

1. Continued plotting data and initial full data set analysis for bulk vs. surface chemistry, yield strength, grain size, and other values.
2. Completed the Milestone M15 - Summary of executed testing plan data input into project database (Excel Flat Table) and delivered it to DOT via upload to the DOT MIS project site.

## Task 4 - Data Analysis and Model Development and Optimization

A high-level summary of these results is presented below:

### GTI/Element Resources

1. Continued causal-based modeling using non-linear ordinary least squares (OLS) regression with single and multiple microstructure forms.
2. Expanded the use of categorical and non-linear continuous relations based on metallurgical principles.
3. Made substantial progress on correlating surface-to-bulk yield strength across all steel types, seamed and seamless, and HSLA and non-HSLA steels.
4. Worked with ASU to assist with data explanations and prioritization for their advanced modeling effort.

### ASU

1. Extend the validation and demonstration with the new provided data sets for both yield strength and ultimate strength.
2. Finalized linear model, quadratic model, Gaussian process model, and Bayesian network model and associated R codes with full 70 samples dataset.
3. Expanded modeling from yield strength to now include ultimate tensile strength.
4. Commenced writing ASU modeling chapter of the draft final report.

## Task 6 - Project Management

1. Submitted Milestone **M15** - Summary of executed testing plan data input into project database (Excel Flat Table) on 10/31/2020.
2. Submitted Milestone **M16** - 9<sup>th</sup> Quarter status report on 10/31/2020.
3. Submitted Milestone **M23** - Conducted 2020 Peer Review #2 of Project (Virtual). Presented on 10/21/2020 and uploaded to the DOT MIS project site.

# **PLANS FOR FUTURE ACTIVITY**

## **(Project Quarter #10: 11/1/2020 to 1/31/2021)**

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In the next quarter the project team will continue work on Task 4. The planned activities are listed below.

### **Task 4 - Data Analysis and Model Development and Optimization**

1. Complete summary of data analysis and model generation and optimization.

### **Task 6 - Project Management**

1. Submit Milestone **M17** - Summary of Data Analysis and Model Generation and Optimization.
2. Submit Milestone **M18** - 10<sup>th</sup> quarterly status report.

Respectfully submitted by,

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**End of Report**