Public Quarterly Report

Date of Report: 9th Quarterly Report-October 31, 2020
Contract Number: 693JK31810001
Prepared for: DOT
Project Title: Improvements to Pipeline Assessment Methods and Models to Reduce Variance
Prepared by: GTI
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For quarterly period ending: October 31st, 2020

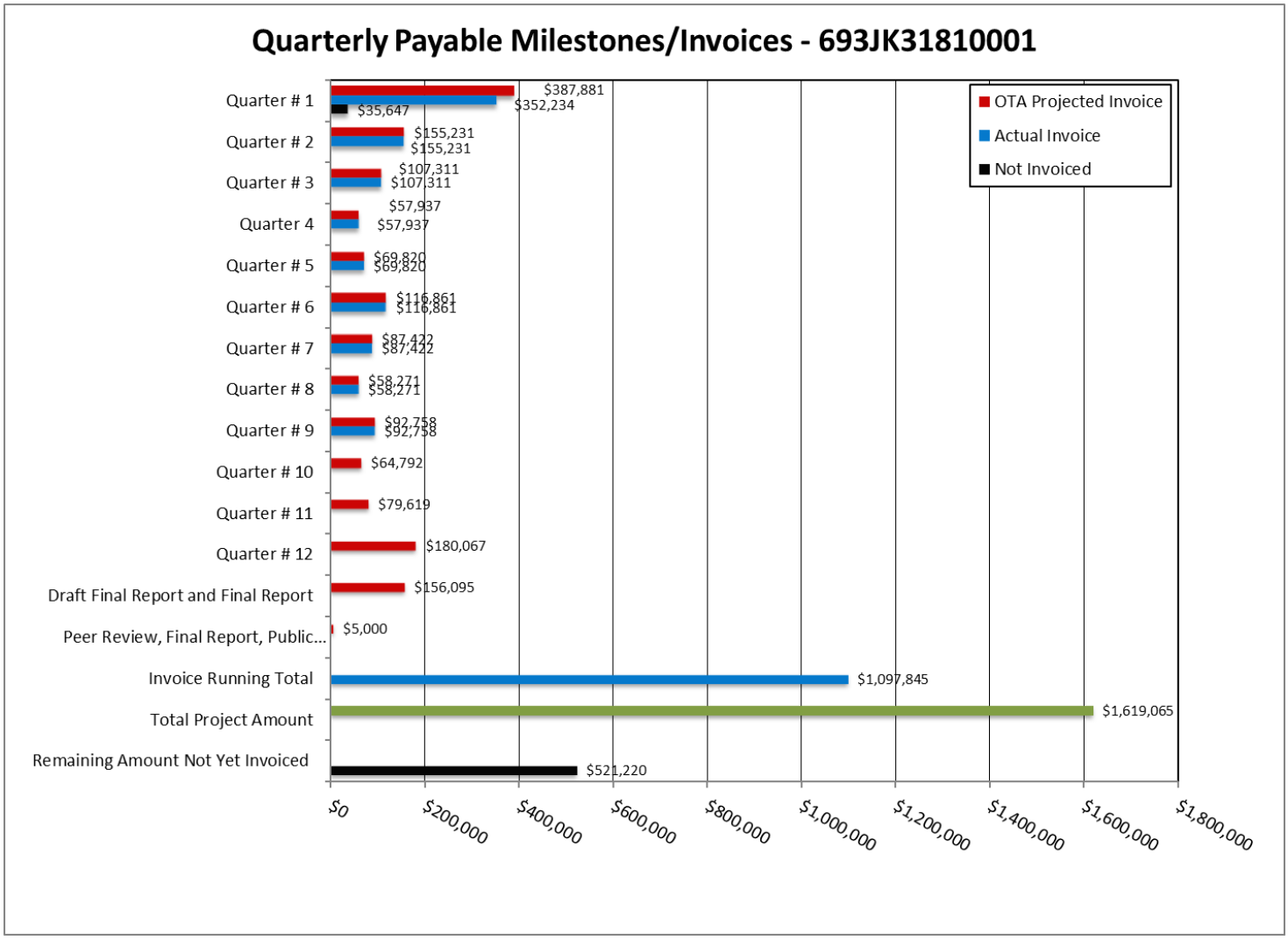
1: Items Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
60	3.3.2.1	Uncertainty Reduction	Integrated Variance Reduction and Bayesian Updating Phase 3 Report	18,482.00	$ -
61	4.3.1	Structural FEM Study	FEM DoE Phase 7 Report	15,505.00	$ -
62	5.3.2.1	FEM Simulation of NDE Signal Responses	Learning and Data Fusion Phase 3 Report	20,501.00	$ -
63	6.3.1	Data analysis	4th Data Analysis Methods Progress Report	33,857.00	
64	9.3.1	Project Management	9th Quarterly Report	4,413.00	

2: Items Not Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
NA	NA	NA	NA	NA	NA

3: Project Financial Tracking During this Quarterly Period:



The invoice that will be submitted will include the following line items:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
60	3.3.2.1	Uncertainty Reduction	Integrated Variance Reduction and Bayesian	$ 18,482	$ -
61	4.3.1	Structural FEM Study	FEM DoE Phase 7 Report	$ 15,505	$ -
62	5.3.2.1	FEM Simulation of NDE	Learning and Data Fusion Phase 3 Report	$ 20,501	$ -
63	6.3.1	Data analysis	4th Data Analysis Methods Progress Report	$ 33,857	$ -
64	9.3.1	Project Management	9th Quarterly Report	$ 4,413	$ -
			Total	**$ 92,758**	$ -

4: Project Technical Status

Item # 60, Task # 3.3.2.1 Integrated Variance Reduction and Bayesian Updating Phase 3 Report

This report summarizes the work done by ASU during the 9th quarter period, which is mainly focusing on the risk assessment integrated with uncertainty reduction using the Bayesian entropy method. The deliverable for Task 3.3.2.1 Uncertainty Reduction: Integrated Variance Reduction and Bayesian Updating is completed.
Observed data (or information) due to various sensor technology advancements can be used to reduce the uncertainty in engineering models and optimize the management of systems. An effective framework for combining new information with existing models is provided using the Bayesian updating technique, in which prior probabilistic models are updated with data and observations. The Bayesian framework enables the combination of uncertain and incomplete information with models from different sources and provides probabilistic information on the accuracy of the updated model. The updated information can then affect the probabilistic risk analysis results. Thus, the probabilistic fracture assessment in the project will be performed by both the probabilistic risk analysis and the Bayesian inference. In real engineering problems, additional formation may be available such as statistical moments (mean or variance, etc.) and range information. That information cannot be directly introduced into the Bayesian method. To combine additional information, a Bayesian Entropy Network (BEN) is used as a generalized information fusion tool to reduce the overall variance. As for the risk assessment, the direct sampling methods are used due to the numerical efficient active learning kriging model. The time consuming fully developed finite element model can be avoided so that computational efforts can be reduced. A demonstration example of risk assessment integrated with Bayesian uncertainty reduction due to the existence of random corrosion surface (loss of materials) was presented to show the feasibility of the framework.

Item # 61, Task # 4.3.1, Structural FEM Study, FEM DoE Phase 7 Report

In the 9th quarter, GTI focused on evaluating differences between different material properties and presentation of FEA results on failure assessment diagrams (FADs). A method was established to present an FEM failure assessment (Level 3) with respect to the break stress that is defined in the steel material model, in addition to the traditional J-integral based assessment. An output of the damage depth is also included, which provides additional insight into expected crack propagation and further reflects variance between materials. It is envisioned that this sensitivity to different materials can help reduce material property related uncertainties.

GTI also attempted to calibrate material properties via simulation of Charpy V-notch tests. The attempts to calibrate a few of the steel material models to match known Charpy impact energies were only partially successful due to certain limitations in the FEM software. Additionally, more comprehensive testing to calibrate the damage model's sensitivity to stress triaxiality, Lode angle, and strain rate are expected to be required for good calibration. This effort has been shelved.

In the next quarter, GTI will focus on producing various FEA-based response surfaces for 3D models of pipes with internal, longitudinal, semi-elliptical surface cracks and external corrosion and a wide variety of steel properties.

Item # 62, Task # 5.3.2.1, FEM Simulation of NDE Signal Responses, Learning and Data Fusion Phase 3 Report

In this quarterly report, stress corrosion cracking (SCC) has been investigated further regarding propagation. The fatigue growth is studied via solid mechanics and fatigue module in COMSOL and propagation data is obtained by applying boundary loading of various cycles. On the other hand, historical measurement with different strength levels (different number of loading cycles) are also investigated which could help us to verify our simulation results. Within this reporting period, the deliverable 5.3.2.1 FEM Simulation of NDE Signal with milestone item Learning and Data Fusion Phase 3 has been successfully completed by MSU.

Item # 63, Task # 6.3.1, Data Analysis, 4th Data Analysis Methods Progress Report

The work in the previous quarters has been focused on developing the tools to quantify uncertainty in risk assessments of pipe segments due to:

- Geometry – explored through FEM simulations
- Loading – explored through FEM simulations
- NDE – explored through simulations

The remaining component of uncertainty to be considered is that due to material properties. Several components of this project needed to be combined to properly address the material property component of uncertainty:

- Material testing
  - o True stress/strain curves to break
  - o Charpy impact testing of pipeline steels
- Development of a suitable constitutive model that captures:
  - o Material yield
  - o Material break
  - o Energy to break
  - o Strain hardening
  - o Material damage – elastic and plastic components
- Validating the assessment results from the FEM simulations through comparison to API579/ASME FFS1 procedures

These tasks have been satisfactorily completed and, in this quarter, we were able to extract three key parameters from the calibrated constitutive models:

1. Material yield point
2. Material break point
3. Energy to break

We also received Charpy test results from DOT PHMSA project “Validating Non-Destructive Tools for Surface to Bulk Correlations of Yield Strength, Toughness, and Chemistry”, Contract. 693JK31810003 that enabled us to attempt to correlate the three parameters above to:

- Full size upper shelf Charpy energy
- Kc – the critical fracture toughness of the material
- The limit state for a given pipeline with specific defect

We were successful in developing very good correlations for all three of these values using 11 of the 12 calibrated models we have.

This result is very promising, and we will extend the analysis to the 54 pipeline steels with enough definition that we have at our disposal.

The correlation models will allow us to predict the limit state of a pipeline segment with a measured set of defects from a calibrated constitutive model alone. This will be a significant simplification of the process that requires less material testing than is needed by the current approaches.

Item # 64, Task # 9.3.1, Project Management, 9th Quarterly Report

All project management reporting requirements have been met.
The 2020 peer review meeting was held in October

5: Project Schedule –

All deliverables scheduled for completion in the eighth quarter were completed as scheduled.

End Project Status Update