PROGRESS REPORT

FAILURE ANALYSIS SIMULATION MODEL FOR THE APMRD–II (Phase 1)

Final Progress Report – July 2016

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As of the end of June 2016, the amended first phase of the Failure Analysis Simulation Model for the APRMD – II is nearly complete. The only obstacle has been the longer-than-predicted running time for the simulations. A final draft of the report on the prototype models will be sent by July 10, 2016 at the latest.

In this short progress report, we list the general tasks that have been completed to-date on the original project (as per CQADS Project #15-001-01, cf. Proposal of February 20, 2015) and on the amendment requested by the NWMO (as per CQADS Project #15-001-01, cf. Amendment of December 9, 2015, finalized on February 9, 2016), and summarize the project's financial and logistic details, as of July 6, 2016. Whenever possible, we highlight the results of the tasks in the form of documents that have been delivered to the NWMO, discussions with the NWMO team of SMEs, or CQADS internal documents.

1. Timeline of Major Tasks Completed To-Date

May
- Original project quality plan (PQP) sent to NWMO (May 19, CQADS-15-001-01-PQP-R000.pdf)
- Initial theoretical considerations (internal to CQADS)

June
- Analysis of simple study system (internal to CQADS)
- PQP returned by NWMO with requested revisions (June 11, APM Project Quality Plan Checklist for CQADS PAH.pdf)
- Set up file system (internal to CQADS)
- Project planning and ontology discussions (internal to CQADS)
- Preparation for first quarterly meeting in Toronto: review of NWMO system documents (internal to CQADS)
- Toronto Meeting: met with NWMO SMEs, presentation of methodology, met with quality assurance specialist
- Upon request from NWMO, sent a simple tutorial illustrating the method (June 24, Data Collection Tutorial (with Demo).pdf)

July
- Develop tagging scheme (internal to CQADS)
- Start of revisions on PQP to meet the ISO-standard requirements requested by NWMO (internal to CQADS)

August (Centre closed for Summer holidays)
- Continuing work on PQP (internal to CQADS)

September
- Initial discussions on system data extraction and visualization (internal to CQADS)
- Initial discussions on causal chain implementation and visualization (internal to CQADS)
- Created object model/hierarchy (internal to CQADS)
- Second version of PQP sent to, and accepted by, NWMO (May 19, CQADS-15-001-01-PQP-R01.pdf)

October
- Start of sentence tagging in NWMO documents (internal to CQADS)
- Visualization of sentence tagging (internal to CQADS)
- PQP compliance - procedural and temporal reports (internal to CQADS)
- Package sent to NWMO with deliverables (Oct 29, CQADS-15-001-01-HTML1-StructRepository-R00.html, CQADS-15-001-01-TREE1-SysComponents-R00.pdf, CQADS-15-001-01-MEMO1-PrepChecklist-R00.docx, CQADS-15-001-01-FIG1-StructRepositoryInfoViz-R00.png)

November
- Preparation for second quarterly meeting in Toronto: selection of pre-prototype chain to suggest to NWMO SMEs (internal to CQADS)
- Toronto Meeting: met with NWMO SMEs, gathered a large amount of datum regarding the system, settled on prototype causal chain
- NWMO need for re-scoping in re: manufacturing process made evident (see discussion in CQADS-15-001-01-PR-Dec-2015.pdf)

December
- Re-scoping of project to include process-mapping of container manufacturing (Dec. 9, Proposal - [15-001-1] NWMO (Phase 1) – Amendment.pdf)
- Settled on final Prototype Causal Chain, including a node on manufacturing containers and limitations of such an approach (email exchange between Alan M. and Patrick B)
- Sent progress report for 2015 (CQADS-15-001-01-PR-Dec-2015.pdf)

January

- Provision of additional support documentation to NWMO for contract amendment (QP_noncomprehensiveselectionfiles.xlsx, NWMO_QP_selectionelevantemails.pdf)
- Additional research on minimum knowledge requirements for predictability to be successful (internal to CQADS)
- Additional research review (ongoing) on relevant existing models (internal to CQADS)
- Developed syntax and description language for causal chain data collection (internal to CQADS)
- Using causal chain data collected in November, developed a more rigorous description of the current causal chain (internal to CQADS)
- Background research on radiation (CQADS_Radiation_Sources_in_Nuclear_Waste_and_Their_Properties.pdf, internal file)

February

- Re-scoping amendment of project to include process-mapping of container manufacturing agreed by Carleton and the NWMO (NWMO_CU_BoilyP_Amdmt No1 to agrmt-PO #01190A-TDS_signed by Carleton_20160209 (002).pdf)
- Background work on manufacturing chain (using internal CQADS files as well as NWMO file VLN_CB_2015.pdf and notes from discussion with NWMO SMEs in November 2015)
- Worked on defining probability specifically in the context of the NWMO model, with considerations on how people perceive and report probability (internal to CQADS)
- Began developing the conceptual model for the causal chain (internal to CQADS)

March [slower month due to fiscal end-of-year commitments, (see email exchange between Patrick B. and Alan M. on March 3, 2016)]

- Started MATLAB implementation of manufacturing process chain (internal to CQADS)
- Sent progress report for the first quarter of 2016 (CQADS-15-0001-01-PR-Mar-2016)

April

- Continued the gathering of data specific to the proposed prototype causal chain and manufacturing process chain (internal to CQADS)
- Continued incorporation of data into the model-structure and setting the parameters to create the implemented prototypes (internal to CQADS)

May

- Wrote a first iteration of the implemented manufacturing process chain prototype model (internal to CQADS)
- Explored the possibility of using theoretical mathematical models instead of simulations for the various prototype chains (internal to CQADS, option ultimately rejected)
- Completed conceptual models for the manufacturing process and pressure transfer interaction causal chains (internal to CQADS)
- Started final iteration of the implemented prototype models (internal to CQADS)

June/July

- Toronto Meeting: met with NWMO SMEs to clarify a number of technical
- Completed final iterations of the implemented prototype models (internal to CQADS)
- Ran a series of functional tests on the implemented prototypes to confirm that they were operating as expected, and completed code validation (internal to CQADS)
- Analyzed some simple behaviour scenarios (internal to CQADS, with input from NWMO SMEs: email exchange and Toronto meeting)
- Completed a draft of a report on the results of the analyses and on the general-level workings of the prototype models, as well as suggested next steps (CQADS-15-0001-01-FR-Jul-2016.pdf, to be sent shortly, along with accompanying files)
- Sent final progress report for Phase I (this file)

2. Project Logistics

Financial Details: The value of the work completed as of July 10, 2016 on the Failure Analysis Simulation Model is shown in the table below:

Invoiced to date		
Quality Plan	$	5,760.00
Components of Structured Data Repositories	$	40,320.00
Causal Chain and Conceptual Prototype Model	$	7,200.00
Prototype Creation	$	70,560.00
Demo Analysis and Report	$	14,400.00
Amendment for Manufacturing Process Model	$	38,000.00
Travel (3 trips + cancelled meeting)	$	3,716.86
Total:	**$**	**179,956.86**

Total Work (hours)	**Projected (Original)**	**Projected (Amendment)**	**Projected (Total)**	**Actual**
Quality Plan	72	325	397	405
Data Collection/Conceptual Analysis	594	65	659	1025
Implementation	882	65	947	1120
Demo Analysis	144	20	164	125
Report	36	0	36	50
Total:	**1728**	**475**	**2203**	**2725**

3. Final Notes and Comments

The first phase has now been completed, and we have prototypes for both the manufacturing process chain and the (isolated) interaction of pressure transfer and corrosion modes in the case of a UFC with a through-wall defect. Conceptually, the project has proven to significantly more complex and complicated that we had initially expected. This is not entirely surprising as our experience has shown us that both von Moltke's Maxim ("no battle plan ever survives contact with the enemy") and Hofstadter's Law ("it's always more complicated than you expect it to be, even when you take into consideration that it's going to be more complicated than you expect it to be") apply to modeling endeavours.

The number of scenarios we were able to run was limited to the available computer resources at our disposal: in the case of the interaction causal chain, we will use the rest of the summer to run some more scenarios in order to see if new emergent properties of the system arise.

The prototype findings, assumptions, and limitations have been summarized in the final report and auxiliary documents, and suggestions for any eventual next steps have also been provided.

CQADS ended up spending considerably more time on this project than had been allotted, even taking into account the amendment (see table above). Again, that is not entirely surprising as the first phase was meant to help us gauge the complexity of the overall project. **As a result we will emphatically not be asking the NWMO for additional funds** to cover this first phase discrepancy as we consider this to be an acceptable side-effect of the required system learning and fine-tuning of our approach.

If the NWMO sees value in this type of exercise, we are open to continuing the analysis starting no earlier than October 2016; however, phases II, III, IV as they were originally suggested will need to be revisited to take into account what we learned about the system and the model in phase I.