ADMINISTRATIVE INFORMATION

1. **Project Name:** Advanced Integration of Multi-Scale Mechanics and Welding Process Simulation in Weld Integrity Assessment

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4. **Project Partners:** Oak Ridge National Lab,
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5. **Date Project Initiated:** January 1, 2004

6. **Expected Completion Date:** December 31, 2006

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** This project is to develop advanced weld integrity assessment procedures by integrating the advanced fracture mechanics and damage mechanics methodology with the latest welding process modeling techniques. This advanced assessment methodology will lead to safer and more economical operation of existing infrastructures *and* sound construction and operating practices of new infrastructures in the industries where welding is a key fabrication technology. The energy savings are realized through: (1) using less tonnage of steels for the same design and operating conditions, (2) reduction in the amount of welding through the use of high strength steels, (3) reduction in repair welding, and (4) reduction in unnecessary post weld heat treatments.

8. **Technical Barrier(s) Being Addressed:** The technical barriers include:
   - Need to refine the ability of predicting the weld metal properties,
   - Lack of correlation between controllable weld process parameters and weld toughness,
   - Lack of an integrated modeling approach for weld integrity assessment, and
   - Lack of suitable fracture toughness test methods for modern high toughness materials.

   The lack of accurate weld integrity assessment procedures leads to overly conservative designs of structures and components, premature shutdown of operations, and even disastrous failures, all resulting in waste of capital and energy that could have been prevented with proper assessment procedures.

9. **Project Pathway:** This project builds upon several key technology elements developed in the industries, national labs, and universities in the areas of weld process modeling and multi-scale mechanics. The two basic technical building blocks of the proposed program are welding process

modeling and multi-scale mechanics (micromechanics, fracture mechanics, and damage mechanics). These two building blocks, together with their associated testing and verification processes, enable the construction of a methodology for advanced deterministic weld integrity assessment. By introducing probabilistic methods, the deterministic procedure is further extended to probability-based weld integrity assessment procedure. This assessment methodology will be the central product of this program.

10. **Critical Technical Metrics:** Currently the baseline weld integrity assessment methodology relies on deterministic fracture mechanics approach by assuming conservative values of various input parameters. The welding process simulation is rarely performed and used in the integrity assessment. The welding process simulation and multi-scale mechanics will be coupled in this project. The assessment procedure will be formulated in a reliability format so the natural distribution of the various input parameters can be taken into account, as opposed to using the most conservative values.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** Not applicable, projects initiated in FY04.

12. **Future Plans:** The following tasks will be performed to accomplish the project objectives.

Task Number	Task Description	Sub-Task Description	Task Completion Date
1	Develop crack driving force relations that correlate crack driving force with material tensile properties, weld geometry, and spatial distribution of material properties in and around the weld	Develop driving force relations under low strain conditions	6/30/2005
		Extend driving force relations to high strain conditions	12/31/2005
2	Develop and refine welding process modeling	Refine weld metal thermodynamic predictions	6/30/2005
		Develop microstructure algorithms for weld metal	6/30/2005
		Explore weld metal toughness prediction algorithms	12/31/2005
		Refine weld metal microstructure algorithms	12/31/2005
3	Develop testing procedures to characterize material's resistance to weld defects. Many of the current fracture toughness test standards are not well suited for modern high toughness materials. Some important features of weld joints are not adequately considered as most of the standard were developed for testing nominally homogeneous materials. The project team will work with relevant codes and standards committees to develop new standards and revise existing standards to address those issues.		6/30/2005
4	Develop deterministic assessment procedures. The focus of this task is the integration of welding process modeling of Task 2 and the multi-scale approach in characterizing driving force and resistance of Tasks 1 and 3.		12/31/2005
5	Validate the deterministic assessment procedure of Task 4 by testing structural components. This task will be run concurrently with Task 4 so each task can benefit from the output of the other task.		12/31/2005
6	Develop reliability based assessment procedure. The result of this task is the culmination of the previous tasks and is the main deliverable of this project. The input parameters that related to both driving force and resistance will be cast in statistical terms. The output of the weld assessment procedure will be reliability index or failure probability.		12/31/2006

13. **Project Changes**: None.

14. **Commercialization Potential, Plans, and Activities:** Our commercialization plan consists of a number of avenues. One of the most effective ways of bringing the weld assessment technology to the widest possible audience is through codes and standards. The project team members plan to continue their work in a number of industry code committees, including API (American Petroleum Institute), ASME B31 (ASME codes for Pressure Piping), ASME Hydrogen Piping and Pipelines Project Team, and AWS (American Welding Society). All these committees have plans to introduce/revise reliability- or risk-based assessment procedures. Therefore, the output of this project is directly relevant and very timely. The other avenue is through our industry partner, PRCI (Pipeline Research Council International). PRCI is a member-based organization with the mission to improve the reliability and integrity of energy pipeline infrastructure through collaborative technology development programs. PRCI member includes all major petroleum pipeline infrastructure companies in the US. It has a proven history of technology deployment. Some of the most widely used pipeline integrity tools were developed and commercialized through PRCI.

15. **Patents, Publications, Presentations:** None to date.