ADMINISTRATIVE INFORMATION

1.	**Project Name:**	Structurally Integrated Coatings for Wear and Corrosion
2.	**Lead Organization:**	Caterpillar Inc. Technical Center Bldg. E P.O. Box 1875 Peoria, IL 61656-1875
3.	**Principal Investigator:**	M. Brad Beardsley, Caterpillar Inc. ph. 309-578-8514/fax 309-578-2953 Beardsley_M_Brad@cat.com
4.	**Project Partners:**	Oak Ridge National Laboratory, Dr. Craig A. Blue, 865-574-4351, blueca@ornl.gov Oak Ridge National Laboratory, Dr. Camden R. Hubbard, 865-574-4472, hubbardcr@ornl.gov Albany Research Center, Dr. Jeffery A. Hawk, 541-967-5900, hawk@alrc.doe.gov Iowa State University, Dr. Brian Gleeson, 515-294-4446, gleeson@ameslab.gov University of Illinois, Dr. Darrell F. Socie, 217-333-7630, d-socie@uicuc.edu QuesTek Innovations, LLC, Dr. Herng-Jeng Jou, 847-328-5800, hjjou@questek.com University of Missouris-Rolla, Dr. David Van Aken 573-341-4717, dcva@umr.edu
5.	**Date Project Initiated:**	January 1, 2004
6.	**Expected Completion Date:**	December 31, 2006

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The proposed work effort will develop improved, cost effective surfacing materials and processes for wear and corrosion resistance in both sliding and abrasive wear applications. Materials with wear and corrosion performance improvements that are 4 to 8 times greater than heat treated steels are to be developed. Affordability will be assessed against other competing hard surfacing or coating techniques, balanced with overall materials performance. Where practical, state-of-the-art design and simulation capabilities will be incorporated to guide materials and process refinement.

8. **Technical Barrier(s) Being Addressed:** Materials degradation by simultaneous wear and corrosion is responsible for failure and life reduction of many components such as track undercarriage, ground engaging tools, piston rings and liners, engine valves, pumps, or other mobile systems. Because of the complexity of high wear resistant and corrosion resistant surface modified structures, an empirical approach is not only extremely time consuming and labor extensive, but also limited in the number of potential parameters that can be evaluated. The primary hurdle to the development of coatings to meet the goal of 4-8 times life improvement over current carburized steels is the balancing of the following: choice of substrates, processing constraints, and alloy systems to produce high hardness, corrosion resistant coatings with high toughness. The proposed economic analysis,

materials development, and processing design efforts will combine to address this issue. Coating cracking is perhaps the most difficult technical obstacle to overcome with the usage of extremely hard materials. To overcome this hurdle, efforts will be made to engineer crack free coatings and FGM designs that provide corrosion resistant and compliant base layer(s). Residual stress profiles of coatings will yield additional insights for input into materials and process design. Finally, it is recognized that necessary thermodynamics or kinetic data will be lacking with some of the materials systems utilized for surfacing and this will impact on the accuracy that can be achieved with the materials and processing simulation.

9. **Project Pathway:** Four deposition processes will be investigated for applying the surfacing materials: arc lamp fusing of thermal spray coatings, laser-aided thermal spraying, and plasma transferred arc (PTA). Material design and process simulation capabilities to guide materials and process refinement will be used to aid the development of the cost effective solutions. Systematic process simulation will be performed to augment experiments via numerical modeling based on a combination of transport phenomena, material science, and engineering mechanics. This approach will be effective in optimizing processing parameters to achieve the desired deposited material properties and performance. Potential hard facing materials and deposition processes will be categorized as individual concepts and evaluated for their potential to meet the requirements of the application. For concepts that meet the initial application criteria, more detailed modeling will be developed. These concepts will then be evaluated and a design analysis completed. The most promising candidates will be prototyped and evaluated experimentally. Design of experiments techniques will be used to evaluate each concept to determine the robustness of the design and validate the design assumptions and models. This methodology will streamline the development activity and enable a comprehensive solution to be accomplished.

10. **Critical Technical Metrics:**

- Develop two or more materials systems that provide a 4-8 times wear and corrosion resistance increase over current carburized steels.
- Develop two economically attractive processes for depositing coatings
- Determine intrinsic and extrinsic properties required for modeling of promising materials systems/coatings
- Modify existing and develop new testing methods as needed for quantitatively ranking the toughness of high performance, metallurgically-bonded coatings
- Model the microstructural evolution of high performance coatings during processing
- Analyze the feasibility of each coating process in terms of both economic viability and likelihood of industrialization resulting in “go” or “no go” decisions

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:**

    a. Plasma transferred arc (PTA) welding has been proven to be the most flexible process for application of the materials being developed. Alloy alloys developed have been successfully applied using the PTA process. In contrast, Vortek arc lamp processing shows promise with specific alloys but is unable to process all of the compositions being developed due to a lack of “wetting” of the surface on melting. Economic analysis of the processes indicate that both have potential for meeting the target variable cost for the coatings but the arc lamp process has much higher capital investment cost required.

    b. Based on laboratory abrasive wear testing, four alloys were selected for field test trials. This will include baseline hardfacing materials for comparison.

c. Microstructural modeling has shown promise in predicting key characteristics of the overlays. Microstructures have been analyzed and compared to predictions with high success. A second round of alloy design will utilize the results of this modeling.

12. **Future Plans:**
    a. Confirmation alloys for comparison to microstructural modeling are in process.
    b. A second round of alloys based on the predictions will be made and coating made for comparison to the predictions as well as additional wear testing.
    c. Mechanical/toughness screening of promising coating systems is underway. Completion date end 2006.

13. **Project Changes:** A no cost contract extension is being requested to extend the completion date for the project to December 31, 2007. This will allow for completion of wear testing the second alloy design round.

14. **Commercialization Potential, Plans, and Activities:** Discussions with powder manufacturers for the alloys developed are continuing with the aim to have the alloys marketed by them for use by others. Caterpillar will be concept a production facility for application of the overlays to various components for use in our products.

Patents, Publications, Presentations: Dr. Xiangyang Jiang of Caterpillar Inc. presented a paper, "PTA Hardfacing Material for Earthmoving Equipment Applications" at the International Thermal Spray Conference held in Seattle, WA on May 15-18, 2006. The paper was published in the conference proceedings.

15. **Budget History and Projection, $000:**

FY	ITP	Caterpillar Cost Share
2004 Actual	$338.7	$402.4
2005 Actual	$536.3	$928.9
2006 Estimate	$802.0	$695.7