2009 BFRL Project Description

Project Title: Economics of HYPERCON: Predicting and Optimizing Concrete Performance

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BFRL Program: HYPERCON: Predicting and Optimizing Concrete Performance

Objective: Through qualitative metric development and estimation, assess retrospective economic impacts resulting from BFRL's basic research in support of its HYPERCON Program.

Problem:

What is the problem? Predicting concrete performance is a costly and difficult process. BFRL's HYPERCON research program is designed to develop and apply new measurement science, including materials science understanding and performance prediction, in order to help reduce these costs. **A retrospective economic study is needed as a basis to help direct future HYPERCON Program investments in a way that best meets the most important concrete performance prediction needs of U.S. industry in the most cost effective manner.**

Measurement science leverages the productivity of R&D, enhances quality and process control, and facilitates efficient marketplace transactions for complex, technology-based products and services. Yet the infrastructural nature of measurement science, its hard-to-visualize character, and its diffuse nature makes associated economic impacts difficult to assess.

The need for economic studies of NIST research programs is supported by the National Research Council's (NRC) annual assessments of laboratory programs in the context of NIST's mission. One broad factor on which programs are assessed is the degree to which the institute's measurement science and standards achieve their stated objectives and desired impact.

Why is it hard to solve? For a continuing, strategic basic research (Pasteur's quadrant[i]) program such as HYPERCON, a retrospective study is hard to conduct because impacts to date are primarily qualitative in nature. It is challenging to isolate the effect of HYPERCON through industry-level statistics due to the complexity and scope of the cement and concrete industries. Moreover, the commercial value of HYPERCON's scientific findings is not immediately evident due to the implementation time-lag associated with strategic basic research programs. In 2001, HYPERCON established a consortium of industrial stakeholders, known as the Virtual Cement and Concrete Testing Laboratory (VCCTL), to help identify high-priority research needs, to collaborate in meeting those needs in the VCCTL software, and to serve as a conduit for dissemination of its basic research results. Because consortia members usually must undertake

additional, in-house R&D to fully benefit from the outcomes of R&D alliances such as VCCTL, these economic impact is difficult to evaluate based on tangible results alone.

How is it solved today, and by whom? To date, one of three approaches has been utilized in isolation to determine economic benefits of publicly funded basic research.[ii] Each approach comes with inherent biases. With respect to the economic benefits of R&D alliances in particular, a NIST Program Office study evaluates three distinct dimensions of the benefits to firms collaborating in an R&D alliance—perceptual measures of success (subjective assessment of overall value), patent measures, and financial measures (revenue or cost savings realized).[iii]

Why NIST? Economic assessment of its programs helps BFRL managers meet the measurement science needs of the U.S. building and fire safety industries in a cost effective manner. It helps decision makers prioritize research needs and provides a framework to benchmark program success in future years based on past performance. This project is aligned with the BFRL strategic goal, "Measurement Science for Sustainable Infrastructure Materials" and the core competency, "Performance, durability and service life prediction of building materials." BFRL is the appropriate organization to do this work due to its expertise in conducting economic impact studies of the building and fire safety industries.

Approach:

What is the new technical idea? To date, one of three approaches has been utilized in isolation to determine economic benefits from publicly funded basic research: 1) surveys; 2) case studies; or 3) econometric models. This study will implement all three of these methods in turn to override the inherent biases posed by each approach in isolation. The measurement science challenge can be overcome by garnering qualitative information from VCCTL consortium members and relevant Other Agency HYPERCON sponsors through a survey tool. Each qualitative indicator will be specified as accruing to a given cost/benefit category, stakeholder, and HYPERCON research focus area. In turn, the information will be assessed on a retrospective, year-to-year basis and in comparison to performance results of other concrete/cement research consortia through similar surveys.[iv] The evolution of HYPERCON and VCCTL will be tracked using the conceptual framework of *grounded theory* for basic research: research begins by raising questions to guide the research that are "grounded" in observation (e.g., physical cement/concrete testing), followed by identifying "core theoretical concepts" (e.g., rheology, hydration), then developing tentative "linkages" between concepts and research data, and evolving toward one "core category" that is central, such as cement/concrete performance prediction.[v,vi] The use of grounded theory, which encourages continual re-working of linkages between project components and causal relationships, provides a good context for the establishment of the qualitative effects of HYPERCON. Overall, the three-pronged economic assessment approach provides a rigorous framework that uses qualitative indicators to signify past program successes as well as to inform future HYPERCON project directions.

Why can we succeed now? Success is likely now because the basic measurement science from HYPERCON and the program history of its VCCTL consortium are both at a stage of development that permits qualitative impact assessment. New technical staff with econometrics expertise and some experience with qualitative economic assessment can build on OAE expertise in quantitative measurement of BFRL program impacts.

What is the research plan? BFRL will direct its HYPERCON impact study to focus on modeling and assessing qualitative indicators of the program's expected impacts based on HYPERCON/VCCTL research from FY01 to FY09. These qualitative indicators are being identified in FY08 in collaboration with HYPERCON program and project managers. A summary of preliminary indicators identified for VCCTL consortium members and other HYPERCON stakeholders will be delivered in a white paper to BRFL managers by the end of FY08.

BFRL managers will help direct the nature of surveys to take place to refine the qualitative metrics gathered for each survey subject (stakeholder). Enhanced stated preference and/or revealed preference questions will be formulated and distributed. The gathered qualitative data will be analyzed to determine the most fruitful aspects of HYPERCON over time. HYPERCON as an entity along with individual component focus areas will be addressed. To the extent possible, quantitative information based on construction industry data will be incorporated.

A final theoretical econometric model will be stated in general terms by identifying qualitative measures that can be specified quantitatively. This theoretical model can determine marginal effects of a change in a given variable (attribute), and may be used in the future to track changes and growth in various components of HYPERCON.

Finally, a case-wise comparison between VCCTL and three other concrete/cement consortia will be conducted (SUMMA - Canada, ACBM - US, Nanocem – European Union). Outside experts (e.g. academics and industry economists) and industry leaders who are non-VCCTL consortium members will be consulted for background on industry research needs and technology goals in the short term.

Project success will be achieved with a WERB-approved Technical Note delivered on schedule. The TN will present: 1) HYPERCON stakeholder survey results; 2) a theoretical econometric model; and 3) a case study comparing concrete/cement consortia.

Recent Results: In FY08, Helgeson developed a new approach and research plan for evaluating impacts of BFRL's basic measurement science research programs. A literature review of approaches for basic research program assessment helped identify potential qualitative impact modeling methodologies. These were tested for relevance to HYPERCON, and the most effective overall approach was fleshed out in a detailed outline—the basis for a white paper being developed for BRFL managers by the end of FY08—documenting the literature review, potential modeling methodologies, and supporting cement/concrete industry information. The new approach is expected to yield knowledge and expertise enabling qualitative impact assessment of other BFRL strategic basic measurement science research programs.

Standards and Codes: None

Recent Outputs/Outcomes/Impacts

Output: Helgeson, Lippiatt, and Garboczi, "Economics of Prediction and Optimization of Concrete Performance (HYPERCON): White Paper providing Study Context and Overview," September 2008.

Outcome/Impact: N/A

Anticipated Outputs/Outcomes/Impacts

Output: WERB-approved Technical Note reporting results of retrospective impact study.

Outcome: New knowledge, approach, and expertise for evaluating the qualitative and quantitative impacts of BFRL's basic measurement science research programs in general, and HYPERCON in particular.

Impact: N/A

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[i] Stokes, D. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, D.C.: Brookings Institution Press, 1997. The concept underlying the Pasteur quadrant of research is that the drive for new knowledge and the pursuit of application can be combined in a single effect, here referred to as strategic basic research.
[ii] Martin, B. and P. Tang. June 2007. "The benefits from publicly funded research." SPRU Electronic Working Paper Series Issue *Paper Number 161*: http://www.sussex.ac.uk/spru/documents/sewp161.pdf.
[iii] Dyer, J. et al. August 2006. "Determinants of Success in R&D Alliances." NISTIR 7323: http://www.atp.nist.gov/eao/ir-7323/ir-7323.pdf.
[iv] The Paperwork Reduction Act (PRA) of 1995 requires that OMB approve each collection of information by a Federal agency before it can be implemented. This statute defines "collection of information" to be any identical questions posed to 10 or more members of the public, whether written, electronic, or oral. The PRA is not anticipated to affect the survey methodology adopted by the *Economics of Prediction and Optimization of Concrete Performance* project. Given the range of stakeholders involved in each relevant sub-topic of study interest, it is not expected that any identical set of survey questions will be asked to more than nine individuals. For instance, the questions relevant to industrial users of VCCTL are fundamentally different from those which are appropriate to pose to potential academic users of the software. When nine or fewer response surveys are distributed there is no need to apply for OMB approval.

[v] The purpose of grounded theory is to develop theory about phenomena of interest—such as concrete performance. The theory—concrete performance prediction models—needs to be "grounded," or rooted in observation. In a grounded theory approach to basic research, the research begins with the raising of *generative questions* which help to guide the research but are not intended to be either static or confining. As the research team begins to gather data, *core theoretical concept(s)* are identified. Tentative *linkages* are developed between the theoretical core concepts and the data. This early phase of the research tends to be very open and can take years. Later on the researchers are more engaged in verification and summary. The effort tends to evolve toward one *core category* that is central. Eventually, the research yields *conceptually dense theory* as new observation leads to new linkages which lead to revisions in the theory and more data collection. The core concept or category is identified and fleshed out in detail. The result is the grounded theory, an extremely well-considered explanation for some phenomenon of interest, such as concrete performance.
[vi] Glaser, B.G. and Strauss, A.L. 1967. *The discovery of grounded theory; strategies for qualitative research.* Chicago, IL: Aldine Pub. Co.