packages during drops or fishing operations. Costs were estimated for the normal and off-normal outcomes, including costs for fishing stuck packages, remediating contamination, and opportunity costs from termination of disposal operations.

The multiattribute study produced a recommendation to use the wireline emplacement method, because the total probability of a breached package is estimated to be lower by a factor of about 55 for wireline emplacement versus drill-string emplacement, and the cost of wireline emplacement is estimated to be substantially less. The lower probability of a waste package breach with wireline emplacement results because lowering single packages involves much less weight and facilitates the use of impact limiters on every package. The formidable weight of a package string or a drill string is likely to breach waste packages in the event of an accidental drop. Costs for off-normal event recovery are dominated by delay and decontamination that would ensue from breaching a package. Although more trips are needed in and out with the wireline method, increasing the risk of becoming stuck, the trips are faster, and the resulting minimal risk of breaching a package by an accidental drop leads to the preference for wireline over drill-string emplacement.

Planning for the engineering demonstration is proceeding, with engineering contractors performing design studies, fabricating test packages, and developing a prototype handling/emplacement system. The objective is to demonstrate the entire process, including test packages, handling and transfers, and emplacement/retrieval in the field test borehole. The demonstration will emphasize developmental aspects unique to potential future waste disposal in deep boreholes. Package instrumentation will be used for monitoring of down-hole conditions such as package temperature and acceleration. The demonstration will also focus on the working interface between nuclear materials handling specialists and borehole contractors (e.g., drilling, wireline logging) that would be required for future disposal operations.

Sealing Technology R&D

As discussed above, there is thought to be a need for borehole seals during the thermal period. Many sealing materials are available, and R&D is under way to understand the evolution of representative materials over hundreds to thousands of years. The current approach is to investigate the properties and stability of cementitious and clay-based materials (e.g., bentonite), starting with cements that are used in oil and gas wells because they are used successfully in deep boreholes. Properties and longevity can be effectively studied in the laboratory without the expense of *in situ* testing. Tests of emplacement methods could be implemented in shallower test wells. Eventually, a field test of seal emplacement could be performed at full depth of up to 10,000 ft (3 km).

Technology Challenges for the DBFT

An expert panel recently indicated that the field test borehole is technically feasible, but field experience is limited [15]. The field test borehole will advance international experience with drilling of large-diameter, deep boreholes in crystalline rock. Another challenge is sampling of deep-formation water (free water and pore water) in sufficient quantities and with sufficient preservation of ambient quality for a range of chemical and isotopic analyses. This will be accomplished using an integrated approach that combines available borehole methods with the use of tracers in all